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AN

ANSWER

TO A PAMPHLET ENTITLED

"*A Narrative of Facts,*"

LATELY PUBLISHED

By Mr. *THOMAS MUDGE*, JUNIOR,

Relating to ſome TIME-KEEPERS

Conſtructed by his Father Mr. THOMAS MUDGE;

WHEREIN IS GIVEN

AN ACCOUNT OF THE TRIAL OF HIS FIRST TIME-KEEPER,

AND OF

THE THREE TRIALS OF HIS TWO OTHER TIME-KEEPERS,

BETWEEN THE YEARS 1774 AND 1790,

By Order of the BOARD of LONGITUDE,

At the ROYAL OBSERVATORY:

And alſo the Conduct of the Aſtronomer Royal, and the Reſolutions of the Board of Longitude, reſpecting them,

ARE VINDICATED FROM MR. MUDGE'S MISREPRESENTATIONS.

By NEVIL MASKELYNE, D.D. F.R.S.
and ASTRONOMER ROYAL.

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AN

ANSWER

PREFACE.

WHEN I tried Mr. Mudge's time-keepers, repeatedly, for the Board of Longitude, in the courſe of ſixteen years, at the Royal Obſervatory, never once making any objections to the bringing this trouble on myſelf, but, on the contrary, always helping the time-keepers forward to their trials; or when I gave in to the Board of Longitude my reports of their going from day to day, accompanied with calculations to ſhew their fitneſs or unfitneſs to anſwer the purpoſe they were deſigned for; I could not ſuſpect that I ſhould have the tranquillity of my ſtudies invaded, or my time further taken up, by being drawn into a literary diſpute with the maker of the time-keepers, or his ſon. I believe he was tempted to publiſh the preſent narrative from an opinion that I ſhould not think it worth my while to anſwer it, any more than Mr. Harriſon's pamphlet, and then he thought it might make a temporary impreſſion, ſufficient to anſwer his preſent purpoſe. I ſhall take as little notice as poſſible of the ſcandalous imputations thrown upon me throughout every part of the pamphlet, without any proof whatſoever, and ſhall confine myſelf chiefly to what has a relation to fact.

Mr. Mudge has dedicated his narrative to the Earl of Chatham, as Firſt Lord of the Admiralty, and conſequently firſt commiſſioner of longitude; a well choſen name certainly, if his lordſhip had given his conſent to it; which, however, I am well aſſured, was not the caſe.

He has choſen to introduce, in this place, a very extraordinary aſſertion, hoping, no doubt, ſome of his readers would take it for granted, as he has done; namely, that the Board of Longitude muſt neceſſarily truſt to my report, whether the time-keepers are or are not objects of their attention; and he has prefixed an advertiſement to his narrative, in which he quotes the authority of Doctor Zach, in the Berlin Ephemeris, concerning the ſuperiority of good time-keepers to aſtronomical obſervations, for determining the longitudes of places, and mentions his diſapprobation, in ſevere and pointed terms, of my mode of trying time-keepers at the Royal Obſervatory. I ſhall ſhew the groundleſneſs of theſe pretences in this preface, leaving the diſcuſſion of the proper mode of trying time-keepers to a future place of this anſwer.

He ſays, "Dr. Maſkelyne, from the ſitu-
"ation he ſtands in as aſtronomer royal, is the
"proper perſon to try ſuch time-keepers
"as are offered for the public uſe, and the
"Board of Longitude muſt neceſſarily truſt to
"his

"his report to decide whether they are or are not "objects of their attention." I acknowledge that I am, from my ſituation at the Royal Obſervatory, the proper perſon to try theſe time-keepers; and I will add, that I had a hand, as one of the committee of the Board, who drew up the ſketch of particulars, which, through the recommendation of the Board, were afterwards inſerted in the act of the 14th of his preſent Majeſty, in impoſing this painful taſk on myſelf and my ſucceſſors in office, for it was not ſo ordered in the act of 12th Queen Ann; and that the reaſons of the committee for it, in which I heartily concurred, were to render the trial more accurate and authentic than it could be if conducted by any private perſon.

The excellence of the inſtruments at the Royal Obſervatory, and the frequent obſervations of the tranſits of the heavenly bodies over the meridian, made there in the uſual courſe of buſineſs, will always render the rate of going of the Obſervatory-clock better known than can be expected of the clock in moſt other places. The aſtronomer royal is further allowed an aſſiſtant by government, and there is always one of them, at leaſt, in attendance upon the obſervations, and conſequently ready to wind up the time-keeper at a ſtated

time every day, and compare it with the tranſit clock; ſo that there will never be any occaſion to let the watch run down, or leave it in the care of the maker, or any perſon employed as his agent, which would be making him judge in his own cauſe. Moreover, the perſon intruſted by the public with the charge of the Royal Obſervatory, from his experience in various nice calculations, which ariſe out of his obſervations, and muſt neceſſarily be made to adapt them to uſeful purpoſes, may be preſumed better qualified than moſt other perſons to make accurate calculations of the going of the watch, and to draw proper inferences as to its fitneſs or unfitneſs to keep time in intervals of long duration.

I ſhall now conſider Mr. Mudge's poſition, that the Board of Longitude muſt neceſſarily truſt to the aſtronomer royal's report, to decide whether they (the time-keepers) are or are not objects of their attention. I abſolutely deny this poſition. The Board of Longitude, when they put time-keepers into the hands of the aſtronomer royal to try them, have a right to require that he ſhould keep an account of his obſervavations on their going, in a regular and official manner, and put down the particulars in the order of time, in a book prepared for the purpoſe. The maker of the time-keeper has a right

right to expect the same. Therefore if the astronomer royal did not keep his observations on the watches in this manner, and satisfy the maker of the watches that he did so, by shewing him the registers occasionally, when he may call, at proper times, to look at them, he would, no doubt, make his complaints on the subject to the Board, and obtain redress. The account of the going of the watches at the Royal Observatory is, and has been always, kept in this manner, and the makers of the time-keepers, or somebody for them, have, at all proper times, been allowed freely to come and inspect the registers of their going, and copy off any parts they thought proper.

The register is kept in the following manner: The watch is wound up and compared with the transit-clock every day about noon, and the times shewn by each are immediately noted in the register-book, prepared for the purpose, ruled with red lines horizontally, dividing it into forty intervals, for so many days observations of the watch, and by black lines perpendicularly to divide it into distinct columns, containing the noted times of the watch and clock, the daily rate of the transit-clock, and the elements of the calculations for finding the daily rate of the watch, that is, its loss or gain upon mean time from the preceding day, which is set down in

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the laſt column but one, the thermometer being ſet down in the laſt column. The regiſters of all the various watches, which have been tried at the Royal Obſervatory, have been kept, in the ſame manner, and are ſtill preſerved at the Royal Obſervatory; and to them I appeal for the truth of the facts. I have uſually given in reports, at every Board of Longitude, of the daily rates of watches from the time of the laſt report; from which daily rates the loſs or gain of the watch, from the commencement of its trial, or during any other interval of time, may be deduced by any perſon ſufficiently ſkilled in calculation, whom the Board might employ, or who might be allowed copies of the rates, as well as the aſtronomer royal. I have further given copies of theſe rates from time to time to the makers of the time-keepers, from which they alſo might themſelves, or by the aſſiſtance of others, make the like calculations. On the 4th of December, 1790, when the Board were to take the going of Mr. Mudge's two watches into conſideration, I laid before them a complete copy of the daily rates of the watch, during the twelve months trial, the greater part of which had been given them before in ſeparate parts, at the ſeveral meetings of the Board during the trial; to which I added my inferences of the total errors of the watches, from the beginning of the trial to every particular day,

aſſuming

aſſuming the daily rate of going of the watch from a mean of the daily rates of the firſt month, which aſſumption appeared plainly upon the report which I gave in, and I particularly explained to the Board. I further added the errors of the watches in ſix ſeveral periods of ſix months each, compriſed in the twelve months trial, deduced from the foregoing calculations, and clearly explained the manner in which the deductions were made. Therefore the Board were not obliged to truſt to my report, to decide whether the time-keepers are or are not objects of their attention, for they had all the materials before them neceſſary to form their judgment, and they determined unanimouſly that "as the time-"keepers had not gone, upon the twelve months "trial, with the exactneſs required by the act of "the 14th of the preſent king, they were not "authorized to order further trials of them."

A few days after I had delivered this report of the going of the watches to the Board, I ſent a copy of it to Mr. Dutton, for the uſe of Mr. Mudge, which he acknowledges he has received. He has not called in queſtion the authenticity of the numbers or the truth of the calculations of this report, but only the principle of allowing the rate of going deduced from a mean of the daily rates of the firſt month, which is a matter of argument, and ſhall be diſcuſſed in the ſequel of this anſwer.

After the Dedication, Mr. Mudge introduces his Preface, which being replete with nothing but invectives, I ſhall paſs over unnoticed. He then inſerts an Advertiſement, which he mentions being occaſioned by his having been favoured with the Berlin Ephemeris for the year 1794, and thinks it will add ſome weight to the contents of his pamphlet to obſerve, that profeſſor Zach has demonſtrated in that work, from a variety of experiments and calculations, that good time-keepers are much more to be depended upon, for determining the longitude with exactneſs, than any aſtronomical obſervations whatſoever; and has arraigned with great ſeverity, the mode of trial practiſed by me at the Royal Obſervatory at Greenwich, as contrary to every principle of reaſon and juſtice; and predicts that every artiſt will be rejected in conſequence of its eſtabliſhment, which he attributes entirely to my obſtinate party ſpirit. Not having poſſeſſion of the Berlin Ephemeris, nor, if I had, being able to read it, as it is in the German language, I ſhall take theſe particulars on truſt, as related by Mr. Mudge.

* Though Dr. Zach ſacrifices his own ſcience in complaiſance

* I have made ſome inquiries concerning Dr. Zach, who is ſo oſtentatiouſly held out againſt me. By the beſt accounts I can obtain of him, he is no Profeſſor at preſent, although

complaiſance to time-keepers, I cannot do the ſame. No doubt good time-keepers, and among them Mr. Mudge's, may be very uſeful in ſettling geographical longitudes of places, eſpecially if not very remote from one another, and in caſe there is opportunity to aſcertain the daily rate of their going from time to time, as it may happen to vary. But I ſhould prefer correſpondent obſervations of an eclipſe of a bright fixt ſtar by the moon, made by two aſtronomers furniſhed with proper inſtruments, at places not very remote from each other; and a number of correſpondent obſervations of the tranſits of the moon over the

although Mr. Mudge dignifies him with that title, doubtleſs to give more *weight to the contents of his pamphlet*, and Dr. Zach's condemnation of me. He was formerly a Profeſſor of Engineery, on the eſtabliſhment of the late Empreſs Maria Thereſa, which was aboliſhed with many other public inſtitutions by the late Emperor Joſeph. He then came to England, and was recommended to Count Bruhl, to be tutor to his ſon. He was introduced by the Count to the acquaintance of Dr. Hornſby; by whoſe recommendation and intereſt he obtained the honor of a degree of Doctor of Laws from the Univerſity of Oxford. The Count afterwards endeavoured to obtain for Dr. Zach the honor of being elected a Fellow of the Royal Society, at two different times, the firſt time on the Home Liſt, in 1786, and the ſecond time on the Foreign Liſt, in 1788; in both which he failed; and on Dr. Zach's leaving England, he recommended him to the Duke of Saxe Gotha, to be aſtronomer to his Highneſs; in which capacity, I believe, he has been employed ever ſince.

meridian, compared with thoſe of fixt ſtars, made by two aſtronomers at two remote places, to any time-keeper whatſoever, for determining the relative ſituation of the two places.

As to the mode of trial, which Dr. Zach arraigns with ſo much ſeverity, by which he means the mode of calculating the errors of the watches, I ſhall ſhew the neceſſity and propriety of it in the ſequel, and therefore need ſay nothing about it in this place. I ſhould have been at a loſs to account for this very extraordinary public attack upon me by Dr. Zach, if he had not formerly made a private one on me when he reſided in England, about 1786, in Count Bruhl's houſe, as tutor to his ſon, and ſometimes aſſiſting the Count in his aſtronomical obſervations. He had been a conſiderable time in England, without being introduced to me by any of his friends or my friends, and I did not even know his perſon till he was introduced to me at a meeting of the Royal Society, after he had reſided here ſome time. I then invited him to the Royal Obſervatory. Nevertheleſs I have been informed that, previous to his having been introduced to my acquaintance, he complained of my never having ſhewn him any civilities; which my friends know I have been always ready to ſhew to learned foreigners, and indeed to every one who was properly introduced to me. He next, in converſation

ſation with Sir Joſeph Banks, preſident of the Royal Society and a commiſſioner of longitude, aſſerted that the calculations of the ſun in the nautical almanac, of which I am the conductor, for the board of longitude, were not made in an accurate manner, not being calculated for every day as they ought to be, and as the preface imports, but only here and there, and filled up in the intermediate places by proportion and interpolation. As ſoon as I was told of this charge, I deſired Sir Joſeph Banks to call upon him, in my name, to produce any one inſtance, in any one month of the nautical almanacs of twenty-ſix years, which I had then publiſhed for the board of longitude, where ſuch an aſſertion could be proved. Dr. Zach was informed of this, and for a conſiderable time gave no anſwer to it. At length, upon being applied to again by Sir Joſeph Banks, he ſent him a letter, ſee N° III. of the Appendix, explaining how he came to ſuſpect theſe calculations of inaccuracy, and mentioning three inſtances in proof of his aſſertions. The account of the riſe of his ſuſpicions of errors in the ſun's right aſcenſion and equation of time in the nautical almanac, given in this letter, is very curious. He had found apparent irregularities in the rates of going of three time-pieces, namely a pendulum clock of Mr. Mudge's, Mr. Mudge's firſt time-keeper, and a time-keeper made by Mr. Emery,

all in the poſſeſſion of Count Bruhl, which ſeemed ſometimes to vary by jerks, as he calls them, and ſometimes all three together, and theſe variations he thought could not happen to ſuch excellent machines through their own faults, but muſt be owing either to errors in the ſolar tables uſed in computing the nautical almanac, or to errors of computation in finding the ſun's right aſcenſion and equation of time from them, which are uſed in reducing the obſervations. It is certainly very unfair, to accuſe the nautical almanac of errors of Mayer's tables, ſince they have been generally reputed the beſt extant, fidelity and care therefore in computing from them is all to be expected from us. But I muſt tell this aſtronomer, that ſmall errors in the tables, and he pretends no others, and there are no others, cannot ſerve his turn to account for the errors of his time-pieces, ſince it is the nature of differences of the neareſt numbers in tables not to be ſenſibly affected by ſmall errors of the elements from which they are conſtructed, in ſo much that, for finding the differences of the ſun's longitude or right aſcenſion, or of the equation of time from day to day, it would be indifferent which of the modern tables were made uſe of. Therefore the ſmall errors which may be ſuppoſed to exiſt in the ſolar tables cannot account for the *jerks* of his time-pieces. It remains then to be conſidered whether

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there is reaſon to ſuſpect errors in the calculations of the nautical almanac ſufficient to account for them.

Dr. Zach mentions errors of 0″, 2 of time as occurring in the ſun's right aſcenſion and equation of time in the nautical almanac on the 21ſt and 22d of June 1783 and on 17 April 1786. Sir Joſeph Banks employed the late Mr. Michael Taylor, the celebrated computer, and author of the logarithmic tables of ſines and tangents to every ſecond of the quadrant (which I am about to publiſh) to recompute the places in the nautical almanac which were objected to by Dr. Zach; I have alſo recomputed them myſelf, and my computations agree entirely with Mr. Taylor's; but our computations do not agree with Dr. Zach's. On the firſt day, June 21ſt 1783, we find both the ſun's right aſcenſion and the equation of time in the nautical almanac true to the neareſt tenth of a ſecond. On the ſecond day, viz. June the 22d 1783, we find the equation of time exact in the nautical almanac, though Dr. Zach makes it 0″, 12 greater than there ſet down, which I ſhall ſhow preſently is owing to an erroneous method which he uſes of computing the equation of time; and we find the ſun's right aſcenſion this day 0′, 16 different from what is ſet down in the nautical almanac, and not 0″, 2 as Dr. Zach found it by his computations. On the 3d day, viz. April 17 1786, we found the ſun's right aſcenſion in the nautical

nautical almanac true to the neareſt tenth of a ſecond, and the equation of time to err 0″, 18 of time. All the errors then of the nautical almanac are only, 0″ 16 in ſun's right aſcenſion on one day, and 0″, 18 in the equation of time on another of the three days fixed upon by Dr. Zach. Such are the miſtakes pointed out by a perſon who had complained of frequent miſtakes in the nautical almanac, and which appear on examination to be fewer and leſs than he ſuppoſed, and are indeed the greateſt commendation of it. The ſun's longitude in the nautical almanac on theſe three days agreed exactly with the new computations.

I am perſuaded that the ſun's right aſcenſion and equation of time are generally true to the neareſt tenth of a ſecond in the nautical almanac. I find the ſame daily rate of the obſervatory clock from the ſun's obſerved tranſits reduced by the help of the nautical almanac as from the obſerved tranſits of the fixt ſtars. Therefore the variations which Dr. Zach complains of in the three time-pieces muſt have been owing either to their own irregularities, or the errors of his obſervations of the meridian tranſits of the ſun, or partly one and partly the other. As to their all varying their rates the ſame way together, it is what, from the nature of accidental variations, muſt ſometimes happen in a long courſe of obſervations. His pretence that errors of 0″, 2 of time in the nautical almanac could be pointed out by the time-piece, is

abſurd, ſince it [Mr. Mudge's firſt time-keeper] appears by Dr. Hornſby's regiſter of its going publiſhed by Count Bruhl, as well as by my own trial of it, to be liable to vary its daily rate on two days immediately following one another, ſometimes by the quantity of 3″. Dr. Zach's laying the irregularities of the time-pieces, in his trial of them, to the charge of the nautical almanac, is like Mr. Mudge's laying thoſe of his father's time-keepers, during my trial of them, on ſome ſuppoſed ill treatment of them with me, or unfair calculations of their errors in a length of time.

I mentioned above that Dr. Zach made an error of 0″,12 in his computation of the equation of time on 22 June 1783, and that the fault which he laid on the nautical almanac was really his own. He has given his computations for this day at length, which ſhew that he uſed an erroneous method of computing the equation of time, by omitting to apply the equation of the equinoxes in right aſcenſion (which is equal to $\frac{1}{11}$th equation of equinoxes in longitude, reduced to time, with its ſign changed.) He has therefore fallen into one of the two errors, which were haſtily taken up by the late Abbe de la Caille in his ſolar tables, which I pointed out and corrected in Phil. Tranſ. vol. liv. for 1764, p. 336. My proof of it is this: He makes the equation of time, expreſſed in parts of the equator = equation

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of ☉'s center, + ſum of four ſmall equations, + reduction of ☉'s true longitude to his true AR. But it is by theory, = ☉'s true AR − ☉'s mean AR (both being reckoned from the true equinox) = ☉'s mean AR, from mean equinox + equation of ☉'s center + ſum of four ſmall equations + reduction to equator − ☉'s mean AR from mean equinox $-\frac{11}{14}$ equation of equin. in long. = equat. of ☉'s center + ſum of four ſmall equations + reduction to equator $-\frac{11}{14}$ equat. equin. in long. It is evident this differs from Dr. Zach's formula by $-\frac{11}{14}$ equat. equin. in longitude. Accordingly, if this correction, which in the caſe of his computation, of June 22d, 1783, amounts to 0″, 14, be ſubſtracted from 1′. 25″, 92, his equation of time, it will give 1′ 25″, 80, the true equation of time, and the ſame as ſet down in the nautical almanac. Dr. Zach, by the uſe of this miſtaken method, muſt be liable to an error of 1″, 1 of time in computing the equation of time, when the equation of the equinoxes is at a maximum; which, preſuming his own method to be right, he of courſe charges to the nautical almanac; no wonder then he ſhould think it ill calculated.

Dr. Zach further aſſerts, that the mean time of the day anſwering to any hour of an obſervatory clock cannot be inferred nearer than about one ſecond of time, from the tranſit of the ſun obſerved by the

the time of the ſame clock, and the right aſcenſion of the ſun and equation of time taken out of the nautical almanac for reducing the time, partly on account of errors of 0″, 1, or 0″, 2, in the ſun's right aſcenſion, and equation of time in the nautical almanac, which together he ſays, will make 0″, 3; and partly on account of the effect of nutation upon the equation of time, which, he ſays, is omitted in the nautical almanac, which may amount to 0″, 3; and partly on account of the difference 0″, 3, of the attraction of Venus, ſettled by Mr. Lexell according to Mr. Euler's theory; which corrections altogether make 0″, 9. To this I anſwer; 1. The computation of the mean time anſwering to the propoſed time of a clock depends only on the equation of time ſet down in the ephemeris and the daily rate of the clock, the ſun's right aſcenſion ſet down in the nautical almanac not being at all wanted, and the calculation being better made without it; but if it be uſed, any error of it will compenſate itſelf in the courſe of the calculation. Therefore the mean time deduced will be affected only with the error of the equation of time, which is generally true to the neareſt tenth of a ſecond. 2dly, The effect of the nutation is not omitted in the nautical almanac, being taken in by calculating the ſun's right aſcenſion after the longitude has been corrected by the equation of the equinoxes, which

is the laſt of the four ſmall equations, with the true obliquity of the ecliptic. 3dly, Mr. Lexell's correction of the ſun's longitude for the difference of Venus's action may be liable to ſome doubts, and has not yet, as I know of, been introduced into any aſtronomical tables.

Dr. Zach concludes his letter to Sir Joſeph Banks by condemning my method of keeping the regiſters of time-keepers at the Royal Obſervatory. He, arrogantly and without any proof, ſays "It is "diſapproved by every body acquainted with the "ſubject; that it diſcourages artiſts, particularly "* Mr. Mudge, who, while this method is con-"tinued, will never ſubmit his time-keeper to an-"other trial at the Royal Obſervatory; he then "expreſſes his wiſhes that Sir Joſeph would "bring the aſtronomer royal to lay before the "Board of Longitude the bare regiſters of the

* Notwithſtanding this threat, Mr. Mudge was glad, three years afterwards, to get his two time-keepers introduced at any rate to a third trial at the Royal Obſervatory, with all the *hardſhip* here complained of, in having their accumulated errors ſtated from the commencement of the trial to each particular day. He deſired me, by Mr. Dutton, to receive them, and try them again, without waiting for the directions of the Board of Longitude; which propoſal, however, I did not agree to; but I recommended them to the Board, at their next meeting, on the 29th of November, 1788, for that purpoſe, ſee the minutes of the Board of that day, N° 2 of the Appendix. They were accordingly brought to the Royal Obſervatory, and conſigned to my care on the 22d of June, 1789, which was the commencement of their third and laſt trial.

 "daily

" daily rates of the going of the time-pieces com-
" mitted to his examination, which would ſave
" him the trouble of conſtructing ſuch tables,
" which will ſhew the beſt pendulum clock, art
" has hitherto conſtructed, but a very indifferent
" machine." What Dr. Zach means to find fault with here, is my taking the trouble to compute the errors of the time-keepers from the firſt, and adding it to my report of the daily rates to the Board of Longitude. To be ſure, this method, at the ſame time that it makes the report more complete, points out the errors of the time-keepers, whatever they are, in a full and palpable manner, which no doubt is the circumſtance that gives offence to Dr. Zach and Mr. Mudge. But it points out what it ought to point out, and what it is no leſs my duty than my right as a commiſſioner, as well as trier of the time-keepers, to explain to the Board of Longitude, agreeable to Mr. Mudge's own words, p. 42. " That I ought to give a candid and un-
" equivocal account of all I knew relative to the
" invention, that the commiſſioners might be
" enabled to come to a deciſion with all the
" knowledge upon the ſubject which I was
" capable of communicating." Yet now, in contradiction to this, Dr. Zach and Mr. Mudge would not have me make uſe of my own judgment and experience in theſe matters, and act the part

of a faithful counſellor to the Board, by making what I think proper calculations from the daily rates, to infer the fitneſs or unfitneſs of the time-keepers to keep time well for a continuance; but they would have me leave it to Mr. Mudge himſelf, or his friend Dr. Zach, to make theſe calculations themſelves, by which they might have the readier opportunity of putting their own gloſſes on the trials, and by bold aſſertions and artful calculations, and aſſuming ſuch rates of going of the watches as might be moſt ſuitable to diminiſh their errors, endeavour to make it appear to the Board of Longitude, and to the public at large, that the time-keepers had really come within the limits of exactneſs required by the act of the 14th of the preſent king, when, perhaps, by my method of calculation, founded upon ſure principles, and equally impartial both towards the watch-maker and the public, the very reverſe might appear, as was the caſe in the three ſeveral trials of Mr. Mudge's two time-keepers.

I muſt here ſay ſomething in anſwer to Dr. Zach's accuſing me of an obſtinate party ſpirit. If by this he means, that I am one of a party inimical to time-keepers, and unwilling to give them a fair trial, I deny that any ſuch party exiſts. There is no oppoſition or rivalſhip between the method of finding the longitude by time-

time-keepers, and that by lunar obſervations, diſtinct rewards being aſſigned to each. I ſhall ſhew, in the courſe of my anſwer, that I have been, not only no enemy, but very friendly to time-keepers, and particularly Mr. Mudge's. Mr. Mudge himſelf does not even inſinuate, that any of the other members of the Board are in a party againſt him, for he lays the whole blame on me. But if Dr. Zach means to allude to his double rejection, when he was a candidate to be a Fellow of the Royal Society on the home liſt, at the time he was in England, in 1786, and afterwards on the foreign liſt, in 1788, and ſuſpects me of having taken a forward part againſt him, I muſt ſay he does me injuſtice; and that my behaviour on thoſe occaſions did not deſerve ſuch cenſure. On the firſt, I voted for him, not having been, at that time, made acquainted with his unhandſome attack on me, about the nautical almanac. On the ſecond, which was almoſt two years afterwards, I had ſo far forgotten the injury he had attempted to do me, that I even ſpoke in his favour to ſome of my friends, previous to the time of election, till I was ſtopt ſhort, and reminded, that he did not deſerve that favor of me, whom he had traduced with reſpect to the calculations of the nautical almanac. After this, if I did vote againſt him, I apprehend I ſhall not be thought deſerving the imputation of an

obſtinate

obſtinate party ſpirit. I certainly ſolicited no votes againſt him.

I flatter myſelf, that both my moral conduct and my aſtronomical opinions are and will continue to be held in better eſtimation by other aſtronomers, both at home and abroad, than they have been by Dr. Zach; and I have no doubt, after my expoſition of his miſtaken reaſons for ſuſpecting the nautical almanac of inaccuracy; of his ignorance in attributing his own errors in the calculation of the equation of time to faults in the nautical almanac, and in conſequence charging the nautical almanac with errors where there were none; his falſe reaſoning concerning the computing the mean time from a tranſit of the ſun, reduced by the nautical almanac; and his inſidious and preſumptuous propoſition to have the aſtronomer royal confined in the exerciſe of his right and duty to ſtate to the Board of Longitude ſuch calculations as he ſhall think proper to ſubmit to them, when they are going to decide on the degrees of merits of time-keepers, that Dr. Zach will not be thought a man of ſuch conſummate knowledge and judgment, as to be entitled to lay down the proper method of trying time-keepers, and that his opinions and cenſures will be both thought equally undeſerving the attention of the public, or any impartial perſon.

After

After noticing Dr. Zach's miſtaken cenſures upon the calculations of the nautical almanac, I am happy in the opportunity now offered me of giving a reſpectable teſtimony in their favour, that of Mr. De Lalande, the learned author of the moſt complete treatiſe of aſtronomy extant, at page 145 of firſt vol. 3d edition, juſt publiſhed at Paris, with important additions and improvements, particularly in the aſtronomical Tables. Speaking of Ephemerides he ſays, " On a fait a " Bologne, a Vienne, a Berlin, a Milan; mais " *le nautical almanac* de Londres eſt l'ephemeride " la plus parfaite q'uil y ait jamais eu."

AN

AN

ANSWER, &c.

MR. Mudge's profeſſed deſign in this pamphlet is to invalidate my report to the Board of Longitude, concerning the going of two of his father's time-keepers, in a late trial at the Royal Obſervatory, in order to prepare the way for his preſenting a petition to the Houſe of Commons, in hopes of obtaining that reward from parliament, which was denied him by the Board of Longitude, in conſequence of my report.

The Board of Longitude, under whoſe directions the ſeveral trials have been made, are fully competent to judge of the propriety with which they have been conducted. They have approved my report, and calculations concerning the going of Mr. Mudge's two watches in the late trial, and upon that have unanimouſly determined, that "as they have not gone, upon the twelve-"month's trial, with the exactneſs required by the "act of the 14th of the preſent king, they "were not authorized to order further trials of "them." I therefore need no vindication of my

conduct to the Board of Longitude. But, as the public at large have not the ſame lights to guide them, and my own reputation may ſuffer from my ſilence, I think proper to lay a fair ſtate of the facts before them. I ſhall then ſubjoin animadverſions on the principal paſſages in the pamphlet, to confute the miſtakes in facts, to explain miſrepreſentations, and vindicate the propriety of the mode of calculation, which I have uſed in inferring the errors of the time-keepers in different periods.

It might have been expected, that a perſon publicly calling in queſtion an official trial of his watches, made under the direction of the Board of Longitude, and the calculations made thereon by the Aſtronomer Royal, and unanimouſly admitted by the Board, ſhould have brought ſome ſtrong evidence to ſhew that his watches had been improperly managed, and ſome cogent arguments to ſhew that the mode of calculation, inſtituted for determining on their merits, was unreaſonable. Inſtead of this, the author of the Narrative, Mr. Thomas Mudge, jun. ſon of Mr. Thomas Mudge, ſen. the maker of theſe watches, but whom I ſhall conſider, in the courſe of theſe remarks, as one and the ſame perſon with his father, by whoſe direction and advice, as it is in his cauſe, no doubt, it was written, has, without the leaſt evidence, charged me with being biaſſed by

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ſiniſter motives, uſing unwarrantable practices in the management of his watches, and employing an unfair mode of calculation; and to ſupply the want of evidence neceſſary to give weight to theſe charges, has mentioned a number of little circumſtances, moſt of which have no baſis in truth to ſupport them, and others innocent in themſelves, but greatly miſrepreſented and artfully colored, to make them appear to indicate ill intentions in me to Mr. Mudge and his watches. He has invidiouſly and groundleſsly aſſerted that his watches went better when tried by other perſons than by myſelf; he has carefully ſuppreſſed ſeveral particulars relating to the trials of his watches, which, if they had been candidly mentioned, as they ought to have been, would have thrown a very different appearance even upon his own ſtate of the caſe, but at the ſame time defeated the ends of his publication; and he has made the moſt futile objections to my mode of calculating the errors of the watches, and propoſed another in its ſtead, very improper in this caſe, and which, I am perſwaded, he would not himſelf be bound by on another occaſion.

Whoever looks into this publication muſt be ſtruck with the great profuſion of bold unqualified aſſertions, impeaching my candor and integrity, repeated in almoſt every page, in different terms, but to the ſame purport and the ſlen-

der arguments produced in ſupport of them. I ſhall give an anſwer to whatever has the appearance of facts, and juſtify my conduct and my calculations. The minutes of the Board of Longitude; the works that I have publiſhed for them; the original regiſters of the going of Mr. Mudge's watches at the Royal Obſervatory; the going of his watches in the hands of others, as related by himſelf in this pamphlet, and in one printed by his friend Count Bruhl, ſhall be my documents.

I now proceed to the hiſtory of the various trials of Mr. Mudge's time-keepers, under the direction of the Board of Longitude, at the Royal Obſervatory, and I wiſh the reader will carry in his eye the minutes of the Board of Longitude, relative to the ſame, contained in the appendix to theſe remarks.

Theſe trials relate to three watches, and have been made at various times, during the courſe of ſixteen years, between the years 1774 and 1790: The firſt watch, diſtinguiſhed by the name of his firſt time-keeper, was tried here ſingly, between December 14th, 1774, and March 13th, 1775; and again between November 11th, 1776, and February 26th, 1778. The two other watches, called Green and Blue, from the colour of their caſes, were tried here together at three ſeveral times, viz. from April 20th, 1779, to July 17th, 1780; and again from July 21ſt, 1783, to September 12th, 1784; and

and laſtly a third time from June 24th, 1789, to June 29th, 1790, which is the trial to which his pamphlet principally relates. The trial of his firſt time-keeper took up eighteen months; the firſt trial of the two watches Green and Blue took up fifteen months; the ſecond trial of the ſame took up near fourteen months; and the third and laſt trial of the ſame took up a twelve-month.

It is recorded in the minutes of the Board, held on the 25th of June, 1774, that "Mr. "Mudge ſubmitted the trial of it (his firſt time-"keeper) entirely to the Board, either by Mr. "Maſkelyne, in the ſame way that other time-"keepers have been tried at the Royal Obſerva-"tory at Greenwich, or in any other manner, "that they ſhould judge proper." And the Board reſolved, "That the ſaid watch be ſent "to Mr. Maſkelyne, when he returns to Green-"wich, and that he be deſired to make trial of "it accordingly, and after a proper time to report "the reſult of his obſervations thereupon to the "Board." [I was then abſent from the Royal Obſervatory, at the deſire of the Royal Society, with permiſſion of his Majeſty.] Mr. Mudge's firſt time-keepeer was accordingly brought down to the Royal Obſervatory, on December 13th, and the trial of it commenced the next day, December 14th, 1774. The manner of trial of the watch having been ſubmitted to the

diſcretion

diſcretion of the Board by Mr. Mudge, and by them to me, as above related, and recollecting that Mr. Mudge had formerly expreſſed his opinion to me that Mr. Harriſon's watch had not been ſubjected to ſufficient variations of heat and cold in the tranſit room, (which being a cloſe room on the ground floor is warmer than the outer air by ten degrees in extreme cold weather, and as much cooler in the extreme heats of ſummer) I thought it might be right to ſubject his watch to greater changes, and therefore kept it in the great room, only one eaſy pair of ſtairs above the tranſit room, where from the great number and height of the windows, and its diſtance from the ground, and having no ſtory above it, the watch would be liable to undergo greater degrees of heat and cold than below; and I thought Mr. Mudge could not be offended at my doing in the caſe of his watch what he thought ſhould have been done in the caſe of Mr. Harriſon's.

It was neceſſary, in conſequence, to carry the watch down the eaſy pair of ſtairs before mentioned, every day about noon, to the tranſit room, to compare it, after winding it up, with the tranſit clock, and to carry it back again the ſame way as it was brought down, and depoſit it in the great room till the next day; in this manner

the trial was conducted every day, from December 14th, 1774 to Feb. 11th, 1775, when the watch was found ſtopped. The regiſter ſays "Watch "ſtopt: Hands point to $5^d\ 2^h\ 31'\ 40''$, whence it "appears to have ſtopt yeſterday ſoon after it was "compared. J. H." The hand-writing, and initials of the name, of my aſſiſtant at that time, Mr. John Hellins. The regiſter to February 19th relates that "Mr. Dutton came down to examine "the watch, and ſet it going again, but ſuppoſes "it was ſtopt in carrying from the tranſit room to "the great room." I then compared it with the tranſit clock, and continued the trial in the ſame manner as before, till 13th March, when the watch was again found ſtopped. The regiſter relates, "Watch not going. The hands point to $2^d\ 3^h\ 22'$ "$55''\ \frac{1}{4}$. J. H." The next entry in the regiſter is as follows. "March 19th Mr. Dutton came "to examine the watch. He found the main "ſpring broken, and carried the watch away "with him." I muſt here add, that I have all the reaſon in the world to think that my aſſiſtant, during all this time, carried the watch backwards and forwards every day, between the great room and tranſit room, with the greateſt care. Its rate of going kept gradually accelerating between the beginning of the trial and the ſecond ſtopping, till at laſt, at the end

of

of three months, it went faſter than at firſt by about 4″ a day; but the rate of going was not at all altered by the firſt ſtopping, it going at juſt the ſame rate immediately after it as before, which ſhews that no injury had been done to the watch.

At the Board of Longitude, held 27th May 1775, "Mr. Mudge being attending was called "in, and made objections to the place in which "his time-keeper had been tried at the Royal "Obſervatory; and, being aſked if he would "be ſatisfied to have the ſame tried in the tranſit "room, where the other time-keepers have "been tried [Mr. Harriſon's and Mr. Kendal's] "he declared he would, and then withdrew; and "the Aſtronomer Royal was deſired to try it in "that room accordingly." In conformity to this, the minute of the Board of Longitude of November 2d, 1776, ſtates, that "Mr. Dutton "attended with Mr. Mudge's watch, and Mr. "Maſkelyne was deſired, and undertook, to try it "again at the Royal Obſervatory, in the ſame "room wherein Mr. Harriſon's watch was tried."

On November 11th, 1776, Mr. Dutton brought the watch down again to the Royal Obſervatory, to be tried in the tranſit room, according to the directions of the Board of Longitude juſt related.

At a Board of Longitude, held 1ſt March, 1777,

I made

I made a report of the going of Mr. Mudge's watch from Nov. 11th 1776 to Feb. 28th 1777, a ſpace of 109 days; in conſequence of which trial the Board gave him £. 500, to enable him to make two other watches. The minute of the Board is as follows. "1ſt March, 1777, the "Aſtronomer Royal reported to the Board, that "the watch made by Mr. Mudge, which has "been at the Royal Obſervatory for trial, in con-"ſequence of the reſolutions of laſt Board, had "gained in 109 days only 1′ 19″, and that it is "greatly ſuperior in point of accuracy to any "time-keeper which hath come under his "inſpection; and, the Board underſtanding that "Mr. Mudge hath an intention of making two "other watches of the ſame kind, in order to "endeavour to obtain a greater degree of per-"fection, provided he can have ſome aſſiſtance "from them to enable him to do ſo; Reſolved, "in conſideration of the very favourable report "given by the Aſtronomer Royal, as above "mentioned, that a letter be written to the Navy "Board, deſiring them to cauſe £. 500 to be "advanced to the ſaid Mr. Mudge, to enable "him to complete two more watches accord-"ingly."

On the 7th of June 1777 the Board reſolved that a letter be written to the Navy Board for

paying Mr. Mudge the £. 500 ordered by the laſt Board.

The trial however of the firſt time-keeper was ſtill carried on, and fortunately without any ſiniſter event, for the ſpace of about fifteen months, from Nov. 11, 1776 (when it was redelivered after the main ſpring had been mended) to Feb. 16th, 1778, when the watch ſtopt. The remark of the regiſter is, "Watch "ſtopt. Hands as follows $5^d\ 0^h\ 43'\ 16''\ \frac{1}{2}$, "whence it appears to have ſtopped yeſterday ſoon "after it was compared, but I cannot aſſign any "reaſon for its doing ſo. G. G." [The initials of the name, and the whole in the hand-writing of Mr. George Gilpin, my aſſiſtant at that time.] The next remark in the regiſter is, "Mr Dutton "came down to examine the watch, and ſet it "going again; he found nothing to appearance "out of order; ſet it going again." Two days after, viz. on Feb. 24, it is noted in the regiſter, "After I had wound up the watch I heard a noiſe "in it, as though ſomething catched, and preſently "diſengaged itſelf and catched again, for the ſpace "of three or four minutes, when I heard no more "of it." After the compariſon of the watch with the clock next day, Feb. 25th, there is this remark. "This day the watch loſt a ſecond during "the time of winding it up." The next day, Feb. 26th, after the compariſon with the clock, the watch ſtopped;

ſtopped; the note in the regiſter is, "Watch ſtop-
"ped; hands as follows; $5^d\ 2^h\ 23'\ 49''\ \frac{1}{2}$." All theſe remarks are in the hand-writing of Mr. Gilpin. Nothing is mentioned in the regiſter of the cauſe of the final ſtopping of the watch: Mr. Dutton attributes it to the breaking of one of the two main ſprings which are in the watch.

The daily rate of this watch had been always accelerating. This was the caſe in the firſt trial of it from Dec. 14th 1774 to March 13th 1775, when the main ſpring broke at the end of the time; its daily rate then was quicker than at the beginning by 4″. In the ſecond trial, which commenced Nov. 11, 1776, and laſted 15 months, the rate became gradually accelerated from keeping equal time at the beginning, to gaining 8″, 6 in a day at the end, the middle of Feb. 1778, or by 8″, 6.

It may be proper to remark, that between my firſt and ſecond trials of this watch, it was depoſited by Mr. Mudge with, Dr. Hornſby at Oxford for 4 months, from June 20 to Oct. 31, 1776. The printed account of its going during this time was preſented to me formerly by Count Bruhl, together with my regiſter of its going from Nov. 11, 1776, to Nov. 30, 1777, and one of his own from April 18, 1780, to May 7, 1781, who favoured me with a copy of it, according to his

uſual politeneſs, and that reciprocal communication of aſtronomical matters which has paſſed between us. According to this regiſter, its daily rate was accelerated from firſt to laſt by $1''\frac{1}{12}$, it loſing about $1''\frac{1}{4}$ a day at firſt, and keeping equal time at laſt. Eleven days afterwards it was brought to the Royal Obſervatory, and its rate then was the ſame with its laſt rate at Oxford, keeping equal time.

Having now done with the hiſtory of the firſt watch, I proceed to that of the two others, called Green and Blue, from the colour of their caſes, which Mr. Mudge undertook to make in conſequence of the reſolutions of the Board of 1ſt March 1777, to give him £. 500 to enable him to make them, which ſum muſt, according to the terms of the Longitude Act be deducted from the great rewards, if he ſhould hereafter become entitled to any of them, and was given to him, as an indemnification of his time and expences, if he ſhould not ſucceed.

* Theſe two watches were brought down to the Royal Obſervatory on April 20th, 1779, and put into the tranſit room, and continued going without any interruption till July 17th, 1780, when

* On the 28th November 1778, according to a private note of my own, I repreſented to the Board that Mr. Mudge intended to ſend two watches to be tried at the Royal Obſervatory, in ſix weeks time.

Mr.

Mr. Dutton came down and took them away. The rates of both these watches were gradually accelerated. That of Green was losing at first 3″,7 in a day, and gaining 7″,6 at last; the total variation of its rate being 11″,3; and that of Blue was losing 2″, 8 in a day at first, and gaining 15″, 2 at last, the total variation of its rate being 18″. On the 15th of July 1780, according to the minute of the board of that day, "The Astro-"nomer Royal having acquainted the Board, "that Mr. Mudge had desired to have his two "watches from the Royal Observatory, in "order to make some observations upon them, "he was told, the Board had no objection "thereto."

On the 19th July 1783 the minute of the Board expresses; that "the Board having under-"stood Mr. Dutton was attending, he was called "in, and produced two watches from Mr. Mudge, "which he desired might be tried at the Royal "Observatory.—Resolved, that the Astronomer "Royal be desired to receive the said watches "under his care, try their rate of going, and "report the result to this Board." These watches were those called Green and Blue, which had been tried before in 1779 and 1780. They were accordingly brought down to the Royal Observatory on July 21, 1783, and put on trial in the transit room, as before.

Both

Both the watches kept going uninterruptedly till September 12th, 1784, a ſpace of 15 months, except once on May 18th, 1784, when they went down through neglect of winding up, and it is aſcertained by a note in the regiſter, that they both took $7\frac{1}{4}$ turns of the key to wind them up. They were ſet going again, and neither of their rates of going was altered by this circumſtance. The watch called Green, kept nearly equal time at firſt. Its daily rate of going was afterwards ſometimes accelerated and ſometimes retarded by a few ſeconds; the greateſt rate of loſing being 5″, 2 on December 31ſt, 1783, and the greateſt rate of gaining being 4″, 3 on 26th February 1784; the total variation of rate being 9″, 5. The tendency to gain in fine prevailed; at the end of the trial, on September 12th, 1784, the daily rate was that of gaining 2″, 7 per day, or ſo much going faſter than at the commencement of the trial.

The watch called Blue, was gaining at firſt about a ſecond a day. It ſoon went at a faſter rate, and the general tendency being to accelerate, with ſome fluctuations of going ſlower, it had increaſed its rate of going to 8″ a day, on the 28th of Auguſt 1784: its greateſt rate of loſing was $1'' \frac{1}{4}$, on Auguſt 3d, 1783; the total variation of rate was therefore 9″, 5, which happens to be exactly the ſame as that of the watch Green. At

the

the end of the trial, on September 12th, 1784, it was gaining 5″, 4 in a day, or 4″, 4 more than at the beginning of the trial.

On the 24th of Auguſt, 1784, I made my report of the going of theſe watches to the Board, and of their total errors, as expreſſed in the following minute of the Board. " The Aſtronomer " Royal delivered to the Board an account of the " rates of going of Mr. Mudge's two watches, " from the 5th of March laſt, to the 21ſt of " Auguſt, [the account of their rates for the " time preceding had been delivered in at the " Board of 6th March:] alſo calculations of the " total variations of theſe two time-keepers, from " the 21ſt of July, 1783, to the 21ſt of Auguſt, " 1784; by which it appears, that the watch diſtinguiſhed by the appellation of Green, varied

" 1′. 25″, in the firſt 6 months, beginning
" 20th Auguſt, 1783,
" 7. 6, in the ſecond 6 months, beginning
" 20th February, 1784;

" and that the watch diſtinguiſhed by the appel- " lation of Blue, varied

" 5′. 43″, in the firſt 6 months, beginning
" the 20th Auguſt, 1783,
" 11. 4, in the ſecond 6 months, beginning
" 20th February, 1784;

" and

"and that their rates of going are not therefore "exact enough to merit the great reward given "by act of parliament." I muſt here obſerve, that the rates of going, which I made uſe of in theſe calculations, were taken from a mean of the rates of going during the firſt month of the trial. The Board agreeing with this report, I finiſhed the trial of the watches on September 12th following, and Mr. Dutton took them home on the 14th.

I occaſionally called on Mr. Dutton afterwards, who had been Mr. Mudge's partner before his retirement from buſineſs, and ſince his ſucceſſor, as I had been uſed to do; who informed me of Mr. Mudge's employing himſelf at Plymouth, whither he had retired, in making further corrections to theſe two watches, in order to render them more perfect; at which I always expreſſed my ſatisfaction, and good wiſhes for his ſucceſs. Some time between the meetings of the Board of Longitude of 12th July and 29th November, 1788, Mr. Dutton informed me that he had received the two watches back from Mr. Mudge, with the corrections made to them, and wiſhed me to take them from him, and try their going again at the Royal Obſervatory. I told him I did not think it proper for me to put the watches again upon trial at the Royal Obſervatory, without the previous approbation of the Board of

Longitude, but that I would mention the matter to the Board at the next meeting; which I did accordingly, as appears by the following minute.

" 29th November, 1788. The Aſtronomer " Royal then informed the Board, that Mr. Mudge " had made ſome corrections and improvements " to his watches, and wiſhed another trial might " be made of them at the Royal Obſervatory at " Greenwich. The Aſtronomer Royal was deſired " to receive the ſaid watches into his charge, try " their rate of going, and report the reſult to the " Board."

Accordingly the watches were brought down to the Royal Obſervatory, and depoſited in the tranſit room, about 7 months after, on the 22d of June, 1789; but, on account of an alteration made to the pendulum of the tranſit clock, the trial did not commence till two days afterwards. They continued going uninterruptedly till 22d January, 1790, when they were found ſtopped. The regiſter recites: " On going to wind up the " watch Green, found it ſtopped, the hands point- " ing at 1^h. 9′. This was at 20^h, 26′ per tran- " ſit clock. I am not conſcious of having neg- " lected winding it up yeſterday noon. I am " certain, from a particular circumſtance, of hav- " ing wound it up on Wedneſday the 20th." This is in the hand-writing of my aſſiſtant, Mr. John Croſsley. There is a like remark about the

watch Blue, except that it was found ſtopped, the hands pointing at 0^h, 56′. There is a note to both, written by myſelf; " it ſeems to have ſtopped for " want of being wound up on the 21ſt." Conſidering theſe circumſtances, and that Mr. Mudge's firſt time-keeper had ſtopped twice without any apparent cauſe for its ſo doing (for I do not allow that the carrying it up ſtairs to the great room was the occaſion of its ſtopping the firſt time) and that Mr. Kendal's firſt time-keeper, made exactly after the model of Mr. Harriſon's, had alſo ſtopped after going 22 months, without any injury done to it, or neglect of winding up, I did not then think myſelf authorized to ſay abſolutely that the two watches ſtopped for want of winding up, eſpecially as the aſſiſtant, who ſhould have wound them on the 21ſt January, could not affirm it, and no notice was taken of the number of turns uſed to wind them up on 22d January. On the 26th, or four days afterwards, Mr. Dutton came down, and on my aſking him how long the watches would keep going without winding up, he told me 36 hours; conſidering this, and that both watches were found alike ſtopped, I have no doubt now, that the ſtopping aroſe from a neglect of winding up. When the daily rates came to be copied out of the regiſter, the expreſſion objected to by Mr. Mudge, p. 33 of his pamphlet, " it ſeems to have ſtopped for want of being " wound up," was copied alſo, and it did not then

ſtrike me that it was not ſufficient. Had I been ill inclined to the watches, as Mr. Mudge inſinuates, I ſhould have made no remark at all to explain the cauſe of their ſtopping. No conſequence was drawn prejudicial to the time-keepers from this circumſtance. On the 24th January, two days after their being found ſtopped, I ſet the watch Green in motion, by giving it a circular motion in the plane of the balance; but did not ſucceed to ſet the other in motion in the ſame manner. On the 26th Mr. Dutton came down and opened the watch, and ſet it in motion, from which day the trial goes on as before, without any interruption till the 29th of June, 1790, when the year of trial was completed, allowing five days more of trial, on account of the five days loſt by the watches having ſtopped.

The watch Green, at the commencement of the trial, June 24th, 1789, was loſing about 1″ a day. It went with conſiderable regularity till the latter end of October following. Its rate then became gradually accelerated; on November 28th, it amounted to 4″, 47 gaining in a day; on January 21ſt, 1790, it was 4″, 86 gaining in a day; on March 21ſt, it amounted to 5″, 68, which was its greateſt gaining in a day; it then decreaſed, and on June 27th, two days before the end of the trial, it loſt 3″, 09 in a day, which was its greateſt rate of loſing. The ſum of theſe two laſt rates of contrary

kind is 8″, 77, the total variation of rate. About the end of the trial it was losing 3″ a day, or going 2″ a day slower than at the beginning of the trial.

The watch Blue, lost 2″, 95 on the 25th of June, the first day of the trial. In the beginning of November it kept nearly equal time; on December 1st, it gained 1″, 6 in a day; January 13th, 1790, it lost 1″, 78 in a day; April 14th, it got 2″, 37, and June 20th, it lost 1″, 53. The sum of 2″, 95, the greatest losing, and 2″, 37, the greatest gaining, makes 5″, 32, the total variation of the daily rate. On June 29th, 1790, the last day of the trial, it lost 0″, 37, which is a rate 2″, 58 faster than the rate 2″, 95 of losing, on June 25th, 1789, the first day of the trial. The rates of these watches have accelerated upon the whole during the two first trials, but less in the second trial than in the first; the watch Blue also accelerated in the third trial, but less than before: but the watch Green retarded its rate, this time.

I delivered in the rates of going of the watches to the Board, on August 15th, 1789, March 6th, June 5th, and lastly December 4th, 1790.

The day of the meeting of the Board, on June 5th, 1790, preceded June 29th, the end of the year's trial, by 24 days. I had deferred making out the calculations of the going of the watches in the second half year till after it should be completed; but, from

from their having both gone for the firſt 6 months, within the greateſt limit of exactneſs required by the act of parliament, and ſeeing nothing by a general inſpection of the ſubſequent daily rates contrary to their having gone equally well in the ſecond 6 months, I ſuppoſed they might have gone within ſome of the limits for the whole year; and as that, if it ſhould prove to be the fact, would lead to a further trial of the watches of a different kind to the former, and conceiving it fair to give them the advantage of being cleaned previous to ſuch farther trial, I thought it right to mention my opinion to the Board, in theſe terms, that I believed that one or both of the watches might be found to have gone within ſome of the limits required by the act of parliament, but could not be ſure, not having completed the calculations; and propoſed to the Board to give Mr. Mudge the opportunity to clean his watches, previous to any further trial they might undergo, that no time might be loſt if ſuch an event ſhould take place. The following minute of the Board agrees with this account, in which nothing appears of my opinion founded on conjecture, as it would have been if an abſolute report had been made, and which is generally in writing, on the ſubject.

" The Aſtronomer Royal made a further report
" upon the rate of going of Mr. Mudge's two
" watches, and at the ſame time informed the
" Board, that the year of trial directed by act of

" parliament

" parliament to be made of them at the Royal " Obſervatory at Greenwich, was near expiring. " The Board were, thereupon, pleaſed to direct, " that, upon the expiration of the year's trial, the " ſecretary ſhould acquaint Mr. Mudge, that the " report from the Aſtronomer Royal, upon the rate " of going of his watches, would be taken into " conſideration at the next meeting of the Board, " on the firſt Saturday in December; and if in " the mean while he wiſhes to have them return- " ed to him to be cleaned, previous to their un- " dergoing ſuch farther trial as the Board may " direct, he is to make application for them to " the Aſtronomer Royal." The report upon the rate of going of Mr. Mudge's two watches, mentioned in the minute, is nothing more than the daily rates of the watches then delivered in, without any further concluſions deduced from them. I mentioned to Mr. Dutton alſo, ſoon after, in the ſame terms, my opinion about the watches, which he allows to be rightly repreſented. I ſcarcely, if at all, mentioned this opinion to any body elſe.

In conſequence of what I had mentioned at the Board, Sir Harry Parker, the Secretary to the Board, wrote a letter to Mr. Mudge, informing him that my report of the going of his two watches would be taken into conſideration at the next meeting, and deſiring that he would ſend for his watches from

from the Royal Obſervatory, and clean them, if he thought fit, previous to their undergoing ſuch further trials as the Commiſſioners of Longitude may direct; which he afterwards declined.

At the meeting of the Board, on 4th December, 1790, I gave in a written account of the rate of going of Mr. Mudge's two time-keepers during the whole twelve-month's trial at the Royal Obſervatory, with my calculations of the errors of the watches in the ſeveral periods of ſix months contained between 24th July 1789 and 29th June 1790. The rates of going made uſe of in the calculations were deduced from a mean of the daily rates of the firſt month, according to my uſual method. The errors in the ſeveral periods, as mentioned in the minutes, were as follows:

Errors

Errors in Time-keeper marked Green.

Beginning with (1789)		and ending with (1790)		are
July	24	Jan.	29	+ 2′. 41″
Aug.	24	Feb.	28	+ 4. 6
Sept.	24	Mar.	29	+ 5. 28
Oct.	24	Apr.	29	+ 7. 4
Nov.	24	May	29	+ 6. 5
Dec.	24	June	29	+ 3. 36

Errors in Time-keeper marked Blue.

Beginning with (1789)		and ending with (1790)		are
July	24	Jan.	29	+ 3′. 5″
Aug.	24	Feb.	28	+ 4. 10
Sept.	24	Mar.	29	+ 5. 11
Oct.	24	Apr.	29	+ 6. 35
Nov.	24	May	29	+ 6. 31
Dec.	24	June	29	+ 6. 0

Upon

Upon which the Board reſolved unanimouſly, that as the ſaid time-keepers had not gone upon the twelve-month's trial, with the exactneſs required by the act of the 14th of the preſent king, the Board were not authorized to order further trial of them.

Mr. Mudge preſented a memorial to the Board, at their meeting June 11th, 1791, as follows:

" To the honourable the Commiſſioners of
" Longitude.

" The memorial of Mr. Thomas
" Mudge, watch-maker.

" Your memorialiſt begs leave to ſolicit the at-
" tention of the honourable Board to the time-
" keepers he has conſtructed for the diſcovery of
" the longitude at ſea, and humbly hopes, that
" though, during the time of their public trial,
" they have not been adjudged to go within the
" limits preſcribed by act of parliament, yet that
" this honourable Board are of opinion they are
" ſuperior to any that have hitherto been invent-
" ed, and are conſtructed upon ſuch principles
" as will render them permanently uſeful; and
" therefore, in conſideration of their utility, and of
" your memorialiſt having induſtriouſly employed
" near twenty years to bring them to the perfec-
" tion they poſſeſs, he truſts that this honourable
" Board will exerciſe the powers veſted in them
" by parliament, and will give to your memorial-

" iſt, upon making a diſcovery of the principles " upon which his time-keepers are conſtructed, " ſuch a ſum of money as his invention and great " labours ſhall to this honourable Board appear " to deſerve.

" And, as additional evidence to the regiſter of " the Aſtronomer Royal of the goodneſs of the " rate of going, of your memorialiſt's time-" keepers, he begs leave to preſent herewith a re-" giſter of their going for near ſix months paſt, " during which time they have been in the poſſeſſion " of Mr. William Dutton; and he alſo begs to " add, that the firſt time-keeper made by him " has been now going for upwards of ſixteen " years, during which period it has been in the " hands of the Aſtronomer Royal, Dr. Hornſby, " his excellency Count Bruhl, the late Admiral " Campbell, and other gentlemen of great re-" ſpectability; and, from the time it was com-" pleted to the preſent time, it has gone with " ſuch an uniform degree of excellence as evi-" dently to make it appear, that the principles " upon which your memorialiſt's time-keepers " are conſtructed, are permanent in their na-" ture."

Altho' the Board had determined, at their meeting 4th December 1790, that the watches had not gone within the limits of exactneſs required by the act of the 14th of the preſent king,

and

and that therefore they were not authorized to order further trial of them, (which might lead to Mr. Mudge's becoming intitled to ſome of the ſpecific rewards appointed by the ſame act of parliament) yet they had a diſcretionary power, by a particular clauſe of the act, to give leſs rewards for inferior improvements as they ſhould think proper. The Board did not chuſe to exerciſe this diſcretionary power in the preſent inſtance: nothing to explain the motives that might guide their opinions in not granting this favour to Mr. Mudge is put on the minutes. I apprehend, however, that the principal circumſtance, which prevented their acceding to Mr. Mudge's wiſhes, was their not allowing the principal allegation of the memorial, not being of opinion that theſe time-keepers are "ſuperior to "any that have hitherto been invented, and are "conſtructed upon ſuch principles as will render "them permanently uſeful." It was mentioned at the Board "that other watches had been "made, by other watch-makers, ſuperior to Mr. "Mudge's; for inſtance, one made by Mr. "Arnold, tried at the Royal Obſervatory for the "ſpace of 17 months, in 1779 and 1780, above "10 years ago, and at the very time when Mr. "Mudge's two time-keepers were firſt tried alſo "at the Royal Obſervatory; another made by "Mr. Arnold, and tried by Mr. Everard at

" Lynn, for the ſpace of 4 years and 4 months,
" from Nov. 11th 1785 to March 25th 1790;
" and one made by Mr. Emery, and tried by
" Count Bruhl, for the ſpace of 14½ months, in
" 1784 and 1785, and again for the ſpace of 15
" months, in 1788, 1789, and 1790; that Meſſ.
" Arnold, Earnſhaw, and Emery, ſell time-
" keepers at moderate prices; that ſeveral other
" perſons make watches of this kind, which are
" well ſpoken of, but whoſe goodneſs has not
" been as yet ſo well aſcertained as thoſe of the
" three perſons above mentioned. That if the
" Board was to purchaſe Mr. Mudge's two
" watches, with the ſecret of their conſtruction, at
" the propoſed price of £. 2000, they would give
" a decided preference to Mr. Mudge's time-
" keepers above thoſe of others, which would be
" doing injuſtice to others who had made as
" good, or better, and would moreover bring
" other claimants on the Board for the like remu-
" nerations, which the Board might not think
" themſelves authorized to grant, and yet not
" know how fairly to refuſe; and that Mr. Ar-
" nold, in particular, in a late publication, has laid
" in ſuch a claim on this very ground." Theſe ob-
ſervations had doubtleſs their weight in determin-
ing the judgment of the Commiſſioners upon Mr.
Mudge's memorial.

HAVING

HAVING now ſtated the facts relative to the trials of the time-keepers, and the deciſion of the Board upon them, I ſhall make my remarks on the principal paſſages in Mr. Mudge's pamphlet, to confute the miſtakes in facts, to explain the miſrepreſentations, and juſtify the propriety of the mode of calculations which I have uſed in inferring the errors of the watches in different periods.

Mr. Mudge, in the very beginning of his pamphlet, goes out of his way to ally his cauſe with Mr. Harriſon's; tells his readers that Mr. Harriſon, contending with all the oppoſition Dr. Maſkelyne could give him, obtained the reward of £. 10,000, and, upon petitioning parliament, got the remainder of the £. 20,000.—I made no other oppoſition to Mr. Harriſon than the reſt of the Commiſſioners did, in order to ſecure to the public the full diſcovery of the principles and conſtruction of the watch: as ſoon as he had done this, they granted him their certificate to enable him to receive as much as, with what he had received before, on his return from his two voyages to the Weſt Indies, made up the ſum of £. 10,000. He put it out of the power of the Commiſſioners to grant him the ſecond £. 10,000 by not complying with the terms of the Act, which required him to produce two new time-keepers, and ſubmit them to

ſuch

ſuch experiments as the Board ſhould think proper, to enable them to judge whether the method was generally uſeful and practicable.

Mr. Mudge's firſt charge againſt me is, that I am biaſſed by a pecuniary intereſt to wiſh ill to mechanics. His words are theſe (ſee note page 4 of his narrative) "Dr. Maſkelyne is particularly "intereſted in the improvement of theſe tables "[the various aſtronomical tables in uſe for the "diſcovery of the longitude] for the conſtruction "of which he receives from time to time conſi-"derable ſums of money from the Board, and "which, he flatters himſelf, he ſhall be able to "bring to ſuch a degree of correctneſs as to en-"title him to one of the ſpecific rewards offered "by the Act. He therefore, of courſe, cannot "wiſh well to the mechanics who are candidates "for the ſame prize, it being his intereſt to have "as few competitors as poſſible." In anſwer to this, I ſhall ſhew that Mr. Mudge proceeds intirely upon a miſtake. I am not particularly intereſted in the improvement of theſe tables; I never received or aſked for any money for the conſtruction of them. The mathematicians who may endeavour to improve the lunar tables, and the mechanics who may endeavour to improve time-keepers, cannot be candidates for the ſame prize; for diſtinct rewards are offered for theſe

ſeparate

ſeparate improvements, by the act of the 14th of his preſent majeſty, differing in that particular from the original longitude act of the 12th of Queen Ann. The ſums of money which are paid to me by the Commiſſioners of the Navy from time to time, by direction of the Board of longitude, are impreſted to me, upon account, to pay the computers and comparers of the calculations of the nautical almanac: I pay them the whole, and produce my vouchers, and paſs my accounts for every farthing of the money I receive, in the ſame manner as other perſons do who receive money from government. Neither do I receive any advantage from the ſale of the nautical almanacs, or other publications of the Board. In proof of this, I here adduce the minutes of the Board of Longitude.

" 3d March, 1792. The Aſtronomer Royal re-
" preſented to the Board, that he had been reflected
" upon in a pamphlet publiſhed by Mr. Thomas
" Mudge, jun. as being particularly intereſted in the
" improvement of the various aſtronomical tables
" in uſe for the diſcovery of the longitude, and of
" receiving conſiderable ſums of money from time
" to time from the Board for the conſtruction of
" them, and requeſted the Board would, by ſome
" minute or reſolution, vindicate him from theſe aſ-
" perſions; and that they would permit him to have
" atteſted copies from ſuch of the minutes of the

" Board

" Board as he might think neceſſary for his " juſtification.

" And the Board having taken the ſame into " their conſideration, unanimouſly reſolved, That " the Board have never ordered any money to be " paid or impreſted to the Aſtronomer Royal, for " the conſtruction or improvement of the tables " above mentioned, or any other work, but what " hath been, and is expected to be regularly " and punctually accounted for, without any benefit " or advantage whatever to himſelf, ſo far as the " members of the Board know or have any rea- " ſon to believe.

" Reſolved, That the Secretary be directed to " furniſh the Aſtronomer Royal with atteſted copies " of ſuch of the Board's minutes as he may think ne- " ceſſary for his juſtification, and that he may have " leave to publiſh the ſame, if he thinks proper."

The extract of the act of parliament of the 14th of the preſent king, prefixed to every nautical almanac, will ſhew that the rewards appointed for the improvements of the lunar tables, and of time-keepers, are diſtinct from one another.

I ſhall now mention facts which prove me not only to be no enemy of, but very friendly to time-keepers. At page 24 of my account of the going of Mr. Harriſon's watch at the Royal Obſervatory, publiſhed in 1767, by order of the Board of Longitude, after pointing out the errors to

which Mr. Harriſon's watch is liable, I add, " nevertheleſs, that it is a uſeful and valuable " invention, and in conjunction with the obſer- " vations of the diſtance of the moon from the " ſun and fixt ſtars may be of conſiderable ad- " vantage to navigation." I have inſerted the following paragraph in the explanation and uſe of the Nautical Almanacs, p. 151, ever ſince the firſt of the year 1767: " If time-keepers ſhould be " brought into uſe at ſea, the apparent time de- " duced from an altitude of the ſun muſt be " corrected by the equation of time, and the " mean time found compared with that ſhewn by " the watch; the difference will be the longi- " tude in time from the meridian by which the " watch was ſet, as near as the watch can be de- " pended upon."

Another proof of my good inclination to time-keepers, may be found in my ready admiſſion of innumerable time-keepers into the Royal Obſervatory at various times, made by various artiſts, Meſſrs. Harriſon, Kendal, Arnold, Mudge, Coombe, Earnſhaw, Brookſbanks, in order to encourage and bring forward ingenious artiſts, and to aſſiſt commanders and other officers of ſhips going to ſea, by ſetting their watches with the meridian of Greenwich, or informing them of their difference from the ſame, and furniſhing them with their daily rate neceſſary to enable

them to find the longitude in the courſe of the voyage. The Royal Obſervatory was founded for the expreſs purpoſe of finding the longitude by help of the lunar motions; but I have foſtered time-keepers no leſs than I have attended to the motions of the moon, as if the obſervatory had been founded for one purpoſe as much as for the other. In particular, I have encouraged the introduction of Mr. Mudge's watches to the Board of Longitude, in order to their being tried at the Royal Obſervatory, as the hiſtory of the trials of his watches fully evinces.

Although the trial which I made of Mr. Mudge's firſt time-keeper in 1774, 1775, and 1776, has nothing to do with his claim to the reward from the late trial of his two time-keepers, yet he has dwelt upon the accident of its ſtopping, after it had been here two months, with moſt ſingular ſeverity towards me, and inſinuations both of improper management of the watch, and ungenerous motives to occaſion it. The driſt of this appears to me to be, as he could not ſhew any ill treatment of the other two time-keepers during three trials, which altogether took up near three years and a half, to endeavour to make the ſtopping of this appear to have been occaſioned by deſign, and thence to lay a ground of ſuſpicion that the other watches might have been ill treated likewiſe, and thence invalidate

my

my account of their going. He ſays, " his firſt " time-keeper, inſtead of being kept in the room, " where the clock was, with which it was to be " compared, was kept in a room on the other " ſide of a court, acroſs which, and up two pair " of ſtairs, ſome of them ſo ſteep as to reſemble " a ladder, it was daily carried for the purpoſe of " obſerving its variation from the clock." This was not the caſe, and I wonder how he came to be ſo ill informed, or took ſo little pains to inform himſelf better, eſpecially as Mr. Dutton could ſo eaſily have given him the requiſite information. The fact is, as I have related before, that the watch was kept in the great room, one eaſy pair of ſtairs above the tranſit room where the clock ſtands, with which it was to be compared every day. I kept it in the great room, that it might be expoſed to greater variations of heat and cold than if it had remained in the tranſit room, becauſe I thought a watch might be liable to undergo greater changes in a ſea voyage. To this I was prompted, and herein I was confirmed, not only by Mr. Mudge's former declarations concerning Mr. Harriſon's watch having been ſubjected to too little variation of temperature in the tranſit room, and by his ſubmitting the trial to the diſcretion of the Board; but alſo by a reſolution of the Board of Longitude, of 11th April,

1767, reſpecting the trial of the two new watches which Mr. Harriſon was required to produce agreeable to the act of parliament of the 5th of the preſent king. "11th April, 1767, In reſpect "to the mode offered by Mr. Harriſon, for the "trial of the two time-keepers above-mentioned "when compleated, the Board was of opinion "the ſame would not be ſufficient, and therefore "reſolved upon the following mode in lieu there-"of, viz. that the ſaid time-keepers, when com-"pleated by Mr. Harriſon, be tried together at "the Royal Obſervatory, for the ſpace of ten "ſucceſſive months, including the extremes of "natural heat and cold, and two months in the "Downs, under the ſame precautions of ſe-"curing the ſaid time-keepers (under locks with "different keys, intruſted to different perſons) as "were made uſe of in the voyage to Jamaica "and Barbadoes; that in caſe the natural heat "of the ſeaſon in the place where the ſaid time-"keepers ſhall be kept at the Royal Obſerva-"tory does not ariſe to the degrees of 86, ac-"cording to Fahrenheit's thermometer, an artifi-"cial heat be applied ſufficient to raiſe the ther-"mometer to that degree."

As to the ſtopping of the watch, I very much queſtion whether it aroſe from the carrying it to and fro between the tranſit and great rooms, as Mr. Mudge alledges: I do not think that a per-

ſon going up ſtairs can make ſudden and quick turns ſufficient to ſtop the watch, and much leſs, when he proceeds with caution, as he would naturally do in a caſe of this kind. But if I ſhould allow Mr. Mudge what he requires, that the time-keeper ſtopped from this cauſe, does he not ſay the worſt thing he could of his time-keeper, and what no other maker of time-keepers, I am perſuaded, would allow to be ſaid of theirs, that it is not fit or too delicate to bear motions which it muſt neceſſarily be ſubjected to, in removing from one place to another, by putting into and taking out of poſt-chaiſes and boats, and carrying up and down the ſides of a ſhip, which are indeed ſteeper than any ladder, though the ſtairs at the Royal Obſervatory are not? How will it then bear the ſhocks of ſome ſeas, which ſtrike a ſhip on the quarter, and will give the watch a violent motion in the plane of the balance?

I muſt here take notice of a miſtatement of Mr. Mudge's, relative to Dr. Hornſby's trial of this ſame watch at Oxford. Mr. Mudge repreſents that, "after he had compleated this time-"keeper, he put it into the hands of Dr. Hornſ-"by, Savilian profeſſor of aſtronomy at Oxford, "thinking it expedient that ſome public cha-"racter, beſides Dr. Maſkelyne, ſhould be ac-"quainted with its going. After Dr. Hornſby,

"whoſe

" whoſe eminence and abilities as an aſtronomer " and man of ſcience are well known to the " world, had tried it for four months, during " which time it went with great accuracy, it " was committed to the care of Dr. Maſkelyne, " as Aſtronomer Royal, to be tried by him at " Greenwich; but it was ſoon found, that if the " time-keeper continued to go under his care in " ſuch a manner as to deſerve the public atten- " tion, it would not be occaſioned by his good " treatment of it, but becauſe it was not an eaſy " matter to do it any injury." And then Mr. Mudge relates the ſtory of the carrying the watch between the tranſit and great room in his manner, which has been before adverted to. I have not the leaſt deſire to detract from the compliments and encomiums which Mr. Mudge has made on my brother aſtronomer, though invidiouſly oppoſed to me, for I wiſh to add to his reputation, by exciting him by my example to co-operate with me in the cauſe of aſtronomy. The fact is, that Mr. Mudge's watch was firſt tried at the Royal Obſervatory for two months, from 14th December 1774 to 10th February 1775, when the *fatal* ſtopping of the watch happened; and again, after being ſet going by Mr. Dutton, for three weeks more, from 20th February to 12th of March, 1775, when the watch ſtopped again, owing to the breaking of the main-ſpring. The watch was

then

then taken away by Mr. Dutton; and after the main-ſpring was mended, and not before, it was, in the following year, put into the hands of Dr. Hornſby, who tried it for four months, from June 20th to October 31ſt, 1776. Eleven days after this it was brought to the Royal Obſervatory, and tried here for 15 months, till 26th February, 1778. Mr. Mudge repreſents that it went with great accuracy with Dr. Hornſby, but if it continued to do ſo with me, it was becauſe I could not do it an injury; and for proof of this, he gives the hiſtory of its carrying backwards and forwards between the tranſit room and great room, which happened near two years before, and above a year before it was put into the hands of Dr. Hornſby, which I have explained before, and vindicated from Mr. Mudge's miſrepreſentations. When the time-keeper was returned to the royal obſervatory, after having been in the hands of Dr. Hornſby, it went at firſt at the ſame rate as it did with him before the removal, and afterwards went full as regularly with me as it did with him; its rate indeed, being gradually accelerated with me, as it had been with him; but my trial laſting 15 months, the acceleration of rate became conſiderable with me, amounting to 8″, and therefore the watch might ſeem to a ſuperficial obſerver to have gone worſe with me than with him, it having only accelerated its rate by about $1\frac{1}{2}$″ in the courſe of his

four months trial *. My trial of the time-keeper was put an end to by the watch ſtopping, which Mr. Dutton attributes to the breaking of one of the two main-ſprings which are in the watch. Mr. Mudge ſtates, that I informed Mr. Dutton, that the time-keeper ſtopped the firſt time two or three hours after it was wound up, though upon Mr. Dutton's going to Greenwich to ſet it going again, upon obſerving the hour at which it had ſtopped, he found it to be exactly at the time of its being uſually obſerved. The note in the regiſter ſays, the watch appears to have ſtopped ſoon after it was wound up, agreeable to Mr. Dutton's remark. I apprehend Mr. Dutton has applied to the firſt ſtopping the information that I gave him relative to the ſecond ſtopping three weeks afterwards, by the breaking of the main-ſpring, which really happened two or three hours after the winding-up.

Mr. Mudge ſays, p. 9, that "in ſpite of the "Doctor's wiſh, that the [firſt] time-keeper "ſhould not appear to have ſuch merit as to en-"title it to the attention of the public, after it had "been tried by him for a conſiderable time, the "Board of Longitude, by way of encouraging "him to make another, ſo as to become pro-"perly a candidate for the ſpecific rewards of

* All this appears from Count Bruhl's printed account of the going of the watch, in Dr. Hornſby's and my trials of it, which I have referred to in p. 35.

"the

" the act of parliament, thought proper to give " him £. 500." This is a very unfair and a very ungrateful misrepresentation of the matter. It appears by what I have said, p. 33, and by the minutes of the Board, that it was in consequence of my favourable report of the going of this time-keeper, that the Board gave him £. 500, and that not to enable him to make only one but two more time-keepers, which he thought he could make more perfect than the first.

As a farther proof that I was far from wishing ill to the reputation or success of his time-keepers, but on the contrary was a zealous well-wisher towards them, I must mention, that the plan of giving £. 500 to Mr. Mudge, to enable him to make two more time-keepers, originated in a conversation which passed between him and Dr. Shepherd and myself (both Commissioners of the Board of Longitude) at his own house, a short time previous to the Board of March 1st, 1777. Upon his saying that he thought he could make other time-keepers more perfect than the former, we expressed our wishes that he would do it; to which he answered, that it would be a loss to his family, if he should make them, and not succeed to obtain the reward promised by act of parliament. We then asked him what it would cost him to make two more time-keepers? he answered, £. 400 or £. 500; upon which we told

 him,

him, we would mention it to the next Board, which we did accordingly.

From p. 9 to 12, and in p. 31, Mr. Mudge ſpeaks of the accurate going of his time-keeper in the hands of the Duke of Saxe Gotha, and his aſtronomer Dr. Zach, for upwards of two years, by which the latter was enabled to aſcertain the longitudes of ſeveral places with a greater degree of preciſion than had ever been done before; and alſo ſays that in two voyages to Newfoundland, in 1784 and 1785, it was found by the late Admiral Campbell to go ſo well, as to determine the longitude to about one mile and a quarter upon the firſt voyage, and to ſix miles and an eighth upon the ſecond; which latter going was ſeven times more exact than that of the time-keeper made by Mr. Kendal, as a copy of Mr. Harriſon's, which during that voyage the admiral had alſo under his care; and that the admiral has repeatedly declared, that in his opinion ſuch time-keepers were capable of anſwering every nautical purpoſe that could be required of them. And he relates, that "the admiral, in his return "from his ſecond voyage to Newfoundland, one "evening, when near the end of the voyage, pre-"dicted to ſome of the gentlemen belonging to "his ſhip, they ſhould ſee the Lizard the next "morning, which actually happened; and that "he was enabled to keep going on all night at

"a con-

" a conſiderable rate, while the commanders of " the other ſhips durſt not ſail on at the ſame rate; " and that the reckoning kept on board the " other ſhips fell very far ſhort of the reckoning " Admiral Campbell, by the aſſiſtance of the time-" keeper, had been enabled to keep on board " his."

Theſe accounts of the going of his firſt time-keeper in the hands of Dr. Zach and Admiral Campbell, ſeem to be introduced here to ſhew that it went better in the hands of other perſons than in mine, and thence to ground a ſuſpicion that it had been ill treated at the Royal Obſervatory, and moreover to endeavour to invalidate my account of the going of the time-keepers at the Royal Obſervatory. This is a ſhort way of getting rid of long trials; but I muſt not ſuffer all the care and pains I have taken to ſcrutinize into the merits, as well as the defects of theſe time-keepers, to be thus blown away by a ſide wind, and ſo many official obſervations of h m rendered nugatory by ſuch weak pretences.

The argument in favour of the time-keeper from Dr. Zach's determination of the longitudes of ſeveral places by it, with a greater degree of preciſion than had ever been done before, appears to me abſolutely inconcluſive, and a manifeſt argument in a circle. I do not mean to call his obſervations in queſtion, but I may, I think, be

allowed to entertain ſome doubts concerning the ſolidity of his judgment, after his miſtakes concerning the nautical almanac, which I have explained in the preface. I ſay then, that no obſervations, however accurate, can be ſaid with propriety to have ſettled the longitudes of places by the time-keeper, with a greater degree of preciſion than had ever been done before, and at the ſame time to have proved that the time-keeper is an accurate machine; for it can be only from a ſuppoſition of the accuracy of the time-keeper, that it can be preſumed to have determined longitudes more accurately than they were known before; or it can be only from a ſuppoſition of its having determined longitudes accurately, that it can be preſumed to be an exact machine. But the firſt ſuppoſition, that of the accuracy of the time-keeper, is an aſſumption of the very thing in queſtion; and the other ſuppoſition, namely, that it has determined the longitudes more accurately than before, is aſſumption of a thing without proof, and therefore can afford no baſis to an argument for the merit of the time-keeper to reſt on. The time-keeper may have done more ſervice to geography, from this very circumſtance of its having ſettled the longitudes of places, which were not well determined before; but it might have done more ſervice to itſelf, I mean by eſtabliſhing its own credit, if it had been applied to determine over again the longitudes of places

which

which had been well ſettled before, and had given them agreeable to the former reſults.

I knew Admiral Campbell very well, and was informed by him that when young he cultivated the acquaintance of the late Dr. Bradley, then Aſtronomer Royal, who was the firſt of practical aſtronomers ſince the invention of teleſcopes, as Tycho Brahe was before*. From him no doubt the Admiral learnt many particulars relative to aſtronomical inſtruments, as well as the method of uſing them. Accordingly, being a captain in the Royal Navy, about 1756, when Mayer's Tables were ſent over here for determining the longitude, he was fixed upon by the Lords of the Admiralty, as the propereſt perſon to make the neceſſary trials on ſhip-board, to enable the Commiſſioners of Longitude to determine whether obſervations, for this purpoſe, could be taken at ſea with the deſired accuracy. His obſervations were calculated by Dr. Bradley, by which it appeared that the neceſſary obſervations might be made with ſufficient exactneſs; obſervations, let me add, which are now happily well underſtood and practiſed, with the help of the nautical almanac, both in the navy and merchant's ſervice. Admiral Campbell, having had ſo conſiderable a ſhare in recommending the lunar

* See an account of his obſervations in the Appendix.

method

method of finding the longitude to public notice, cannot be ſuppoſed to have neglected the practice of it in his own voyages; in fact, he was furniſhed with Hadley's quadrants, as well as with Mr. Mudge's time-keeper, and uſed both methods, either as a check upon, or in confirmation of each other, as might happen to turn out. The admiral was too wiſe to neglect the practice of the lunar method, which is an abſolute method of finding the longitude, whenever loſt; whereas that by a time-keeper is only a mode of keeping the longitude on from one known place to another, or from that determined by a lunar obſervation to the next obſervation, or to ſeeing land. Being furniſhed with theſe two concurrent helps, he might venture to predict that in the courſe of the night he ſhould get ſo far up the channel, as to be in ſight of the Lizard point the next morning, and knew that he ſhould run no hazard by going on at a conſiderable rate in the night, which is attended with no particular danger if the latitude is well known, not to mention that the Lizard lights may be ſeen at 20 miles diſtance in fair weather. This agrees with the note, p. 15, that he declared to gentlemen on board his ſhip, that the time-keeper contributed very greatly to induce a confidence of his ſecurity, and that were he ever to go to ſea again, he would never be without ſuch a time-keeper, if it was poſſible for him

to

to obtain one. The expreſſion contributed to induce a confidence of his ſecurity, implies he had another ſource of confidence; and what could that be but the lunar obſervations, he practiſed during the courſe of the voyage, which at once corrected the errors of his common ſhip's reckoning, and ſhewed him what degree of dependance he could place upon the time-keeper?

The accuracy of the determination of the longitude to one mile and a quarter in the firſt voyage, and ſix miles and an eighth in the ſecond, is indeed very ſurpriſing. No account is given whether any rate was allowed for the going of the time-keeper in theſe voyages, the want of which renders the reſult dubious. But I find by Count Bruhl's calculations of the going of Mr. Mudge's firſt time-keeper in the firſt voyage, annexed to three regiſters of his pocket Chronometer, made by Mr. Emery, which he made me a preſent of long ago, that the longitude of St. John's was found in the going out to be $3^h. 29'. 37'', 7$ (when an evident erratum of $10''$ is corrected) and $3^h. 29'. 53'', 8$ in the return, which differ only one ſecond each from thoſe mentioned in the laſt page of Mr. Mudge's pamphlet; and in thoſe determinations no allowance has been made by the Count for the daily rate of the watch, which by Admiral Campbell's obſervations, made at Newfoundland between July 4th and October 24th, 1784, printed with the above mentioned regiſters, by

by Count Bruhl, and inſerted alſo in the laſt page but one of Mr. Mudge's pamphlet, was +0,″ 94. This in 37 days, the length of the voyage out, makes 34″,7, which ſubtracted from 3ʰ 29′ 37″,7 leaves the longitude of St. John's 3ʰ 29′ 3″ by the voyage out, or 41″ leſs than the true longitude. The ſame daily rate in 26 days, the length of the voyage home, makes 24″, 4; which added to 3ʰ 29′ 53″,8 gives the longitude of St. John's 3ʰ 30′ 18″, 2 by the voyage home, or 34″ greater than the true longitude.

Thus the time-keeper in the voyage out determined the longitude only to 10¼ miles, and not to a mile and a quarter, as Mr. Mudge pretends. If perſons, who compare time-keepers, are to take the liberty to allow a rate of going to them, or to let it alone, according as it beſt ſuits their preconceived ideas of the longitudes of places, which are not all perfectly exact, tho' ſet down in aſtronomical books from the beſt data that have yet been procured, we ſhall wantonly throw away the means offered us of judging of the relative goodneſs of different time-keepers, or of correcting the longitudes of places, which in many caſes they may afford us opportunities of doing, when all the circumſtances attending them are clearly and fairly ſet down.

I hope this elucidation of the longitude of St. John's given by the time-keeper, which I have been accidentally enabled to derive from the pa-

pers which Count Bruhl had furniſhed me with formerly, will ſhew the neceſſity of proper details being given, relating to experiments of this nature, and the inſufficiency of any general account of ſuch things; eſpecially where conſequences are attempted to be drawn of ſo much importance as Admiral Campbell's inference, "that the time-"keepers are capable of anſwering every nautical "purpoſe that can be required of them:" upon which Mr. Mudge ſays, immediately afterwards, "great weight ſhould be laid, on account of the "Admiral's ſcientific knowledge and accuracy of "obſervation, for both which he was deſervedly "looked up to in the Navy." If the Admiral ever made ſuch a declaration, which I much doubt, he was probably led into it from theſe miſtaken calculations of the Count, for which he himſelf was not anſwerable.

I have no materials by me wherewith to examine the calculations of the longitude of St. John's, given by the time-keeper in the ſecond voyage, in which he ſays it did not go ſo well as in the firſt; which he attributes to the putting in a new ſpring, inſtead of the old one, which broke in the interval between the two voyages, and, there having been only a few days allowed for adjuſting the time-keeper, after its being taken to pieces and put together again, before it was delivered to the Admiral, who had received his

ſailing orders. I ſuppoſe the main ſpring is meant here, which is indeed ſubject to break in all watches, from its violent tenſion. As this has little to do with the exactneſs of the going of the watch, it does not appear that the changing the ſpring ſhould render it neceſſary to re-adjuſt the watch, nor conſequently that the watch ought to have gone worſe in the ſecond voyage than in the firſt. He ſays, however, that it went with ſeven times the degree of perfection the time-keeper made by Mr. Kendall, as a copy of Mr. Harriſon's, did, which, during the ſame voyage, the Admiral had alſo under his care. For want of knowing all the neceſſary particulars, it is impoſſible to form a proper judgment of theſe aſſertions; I muſt however correct one miſtake in them; the watch, which the Admiral had with him, was not that which Mr. Kendall made as a copy of Mr. Harriſon's, but the third he made for the Board of Longitude, and in which he had departed greatly from the conſtruction of Mr. Harriſon's watch, the eſcapement being of a different ſhape, and there being only one pallet, and that of ruby, inſtead of two of diamond, and no remontoir. This time-keeper went three times worſe than that which he made as a copy of Mr. Harriſon's. Therefore Mr. Mudge's watch in the ſecond voyage went only about twice as well as Mr. Kendall's firſt time-keeper, which was a copy of Mr. Harriſon's, according to Mr. Mudge's own account, which

however cannot be admitted as certain for want of a ſtatement of all the circumſtances.

After all, the run between England and Newfoundland, which only takes up a month, is much too ſhort to afford any argument for the ſufficiency of the time-keeper to determine the longitude in a ſix month's voyage, within the limits required by the act of the 14th of the preſent king, which is the main point in queſtion. Neither does the reſult of the trials ſhew that the watch went better than it did with me, during an equal ſpace of time; for by comparing its going at Greenwich, in four periods, of a month each, between Nov. 11th 1776, and March 11th 1777, it appears to have varied 9″ more in the ſecond period than the firſt, 24″ more in the third period than the ſecond, and 24″ more in the fourth period than the third. But this does not prove that it will always go ſo near; in fact, in the fifth period it varied 52″ more than in the fourth period. See abſtract of the going of this time-keeper, N° IV. of Appendix.

Mr. Mudge relates, p. 13, "that the two new "watches, when completed, were ſent to Green-"wich, and after they had remained there ſome "time, a greater variation having happened in "their going than was expected, his father had "them away again, to adjuſt them with more "accuracy. This being done, they were again, in "the month of June 1789, placed in the hands of

" the Aſtronomer Royal, to be tried purſuant to " the act." I muſt here obſerve, that theſe two watches, when completed, were tried at the Royal Obſervatory, from April 20th 1779 to July 17th, 1780, a ſpace of fifteen months, which conſtitutes a complete trial. In this time, their daily rates became conſiderably accelerated, viz. that of the watch Green by 11″, and that of the watch Blue by 18″; and the errors of the watches on July 17th, at the end of the trials, when corrected according to the daily rates of the firſt forty-one days, were thus, Green had gained 27′. 52″, and Blue had gained 50′. 23″ upon mean time; ſee N° 5 and 6 of the Appendix. Theſe watches, after their re-adjuſtment, were brought down again to Greenwich, on July 1ſt 1783, for a ſecond trial, and not in June 1789, as Mr. Mudge repreſents, which date relates to their third trial, he having choſen here to drop any mention of the intermediate trial of 1783 and 1784*, doubtleſs from an unwil-

* In the courſe of this trial both watches altered their rates of going by 9″, 5; and their errors at the concluſion, when corrected according to the mean daily rates of the firſt month, were thus; Green had gained 9′. 43″, and Blue had gained 19′. 6″. In the trial of 1789 and 1790, the daily rate of Green varied by 9″, and that of Blue by 5″; and their errors at the concluſion, when corrected according to the mean daily rate of the firſt month, were thus; Green had gained 5′. 13″, and Blue 8′. 7″. But the greateſt error of Green was on May 6th 1790, and amounted to 6′. 48″ gain.—See N° 7, 8, 9, and 10 Appendix.

lingneſs

lingneſs to let the public know either that the time-keepers required ſo many trials to point out the errors they were ſubject to, or the number of years neceſſary to correct them, in order to bring them to the relative degree of perfection they had attained in 1789, after ten years from the commencement of the firſt trial in 1779. Such were the advantages given to Mr. Mudge, by ſo many nice experiments on his time-keepers at the Royal Obſervatory, to enable him to gueſs at the ſource of their errors! and ſuch the fairneſs and kindneſs ſhewn him by the Board of Longitude, in indulging him with ſo many chances for the reward!

In p. 13, Mr. Mudge obſerves, that "though "his father had great reaſon to be perſuaded "Dr. Maſkelyne was a determined enemy to the "ſucceſs of the time-keepers, yet his ingenuous "mind was ſo averſe to requeſt that to be done, "which, upon the face of it, would manifeſtly "beſpeak ſuſpicion, that he did not deſire, what Mr. "Harriſon, with the moſt perfect knowledge of "the character of his judge, had wiſely requeſted "before him; namely, that a perſon ſhould be "appointed by the Board to attend at the daily "obſervation of the time-keepers, as a check "upon the Doctor, and that they ſhould be "ſcrewed down in the box in which they were "contained, to prevent any miſchief being done "by removing them from place to place, or put-"ting them down with ſuch violence as machines

"of

" of this nature are not fitted to bear."—Mr. Harriſon did not deſire the watch ſhould be ſecured in this manner, for he was not conſulted about this trial. Having always ſpoken of the watch as a perfect machine, or very nearly ſo, he would have been indignant at the propoſal, and not have choſen to have any thing to do with it. The Board of Longitude ordered the trial, to obtain a better and more particular knowledge of the watch, for which the public had paid ſo much, than they could collect from the trials that had been already made of it (a ſatisfaction which they could not obtain while it belonged to Mr. Harriſon, becauſe he would not ſuffer it to be tried at Greenwich, before it went on the ſecond voyage to the Weſt Indies, although he had once conſented to it) and to enable them the better to judge how to apply it to uſe. His future reward, the ſecond ten thouſand pounds, did not in the leaſt depend on this trial, but on the making two more ſuch watches, and ſubmitting them to ſuch trials as the Commiſſioners ſhould appoint. The mode of trial, which the Board of Longitude directed to be uſed on this occaſion, was grounded on a plan propoſed to them by the Earl of Morton, preſident of the Royal Society, and one of the Commiſſioners, and was intended to aſcertain the truth more fully againſt cavils, and for my ſecurity. See N° 1 of the Appendix, the minutes of the Board of April 26th 1766.

Will

Will any one believe, that if Mr. Mudge had been perſuaded I was a determined enemy to his time-keepers, he, having a great object at ſtake, would, out of falſe modeſty, have declined requeſting thoſe ſecurities from the Board for the protection of them? After the firſt two months trial of the firſt time-keeper, during which it ſtopt ſoon after it was wound up, which he attributes to the carrying up ſtairs to the great room, an eaſy pair of ſtairs not above ten feet high, and which he has thought proper to dwell a great deal upon in this pamphlet, and to endeavour to repreſent as ill treatment of the watch, and a proof of ill intentions in me towards it, he did not deſire it to be locked up, on its being returned to the Royal Obſervatory; nor did he deſire the two other time-keepers to be locked up, during their three ſeveral trials, as he owns himſelf; tho' I propoſed it to him. Does not this manifeſtly ſhew that he then thought his time-keepers equally ſecure without, as with thoſe reſtrictions?

In the 14th and following pages Mr. Mudge relates, that my report of the going of the time-keepers at the Board of Longitude held in July, 1790 [he means June, 1790] was ſo favourable, that it was declared directions ſhould be given at the next Board to apply to the Admiralty for a ſhip in which they might be ſent to ſea, in further compliance with the act; that I had ſeveral times

after

after the year's trial had cloſed, ſaid that both the time-keepers had gone within the limits of the act; that one of them had gone within the ſtricteſt limits appointed by the act, and the other within the moſt extended limits.—Theſe are aſſertions which it is out of the power of Mr. Mudge to prove. To whom did I ſay ſuch things? I ſaid nothing like it to the Board of Longitude, nor to Mr. Dutton, whoſe teſtimony would doubtleſs have been brought againſt me, if I had. I have explained this matter in my hiſtory of the trials of the watches, p. 45, where I have mentioned the extent of what I did ſay to the Board, and alſo to Mr. Dutton, viz. that I believed one or both of the watches might be found to have gone within ſome of the limits required by the act of parliament, but could not be ſure, not having completed the calculations. Mr. Dutton has acknowledged to me, that this is the extent of what I ſaid to him. The watches having gone within the greateſt limit in the firſt ſix months trial, and ſeeing nothing by a general inſpection of the daily rates to ſhew they had erred more in the ſecond ſix months, and wiſhing well to the time-keepers, I was, from the principle that we eaſily believe what we wiſh, led to believe they had gone within ſome of the limits throughout the period of the trial. I was induced to mention what I then believed, without having made the calculations to aſcertain the matter, out of good-will to Mr. Mudge, that he might take the

advantage

advantage of cleaning his watches previous to ſuch further trial, as they might become intitled to, if my opinion of their good performance ſhould be verified upon calculation, and to ſave time, as the Board was not to meet again for ſix months. I ſhould have been very glad if the event had turned out ſo, and ſo I can anſwer would every member of the Board of Longitude have been. But numbers are obſtinate things, and when I came to complete the calculations, I was forced to acknowledge the watches had erred beyond all the limits required by the act of parliament. It was never declared at the Board of Longitude, that directions ſhould be given at the next Board, to apply to the Admiralty for a ſhip, in which the watches might be ſent to ſea, in further compliance with the act. My ſolicitude for the watches being returned to Mr. Mudge to be cleaned previous to ſuch further trial, as they might be appointed to undergo, ſhews, almoſt as plain as any thing can do, that I was not then unfriendly to the watches, for had I not wiſhed well to them, I ſhould have ſcrutiniſed more nicely into their going before I ſpoke about them, and not have taken ſo much pains to recommend the cleaning them to Mr. Mudge, preparatory to further trials.

In page 15 Mr. Mudge accuſes me of having withheld a copy of the regiſter of the going of the

time-keepers from him, till after the meeting of the next Board; by which time, he ſays, I contrived to make ſuch calculations from the regiſter, as to make it appear that neither of them had gone within *any* of the limits of the act: and accordingly, at a Board held in December 1790, in conſequence of my report, it was determined that no further trial of them ſhould take place. I have certainly other buſineſs to do at the Royal Obſervatory, beſides trying and calculating the going of time-keepers, or copying accounts of them. Mr. Mudge, or Mr. Dutton for him, might, at all proper times, have come and inſpected the regiſters of the watches, and copied what they pleaſed out of them; the calculations of the going of the time-keepers were not completed long before the meeting of the Board, on the 4th of December 1790. I thought it beſt to delay giving Mr. Mudge a copy of the daily rates till I could add the other calculations to them. I preſented one copy to the Board, on December 4th 1790, and ſent another copy to Mr. Mudge a few days afterwards. If I contrived to make ſuch calculations from the regiſter as to make it appear that neither of the watches had gone within the limits of the act, Mr. Mudge has employed a great many pages in endeavouring to ſhew them to be unfair and improper.

proper. What weight is due to his arguments on this head, I ſhall conſider preſently.

Another charge againſt me, p. 18, is that, at the cloſe of the year's trial, on June 29, 1790, I did not continue the trial of them for five months longer that they remained at the Obſervatory.—I know of no duty that enjoined me to keep the watches going all this time; and have no doubt, from the whole tenor of Mr. Mudge's pamphlet, that if I had kept the watches going, and they had failed more than in the former part of the trial, he would then have ſaid I had kept them longer than I had any buſineſs to do, or the act of parliament required, purpoſely that I might take the chance of their failing in that additional time.

Mr. Mudge from p. 19 to 31 has endeavoured with ſpecious arguments and artful repreſentations to ſhew that the method I have uſed of calculating the going of the time-keepers is unfair and improper: and to ſubſtitute one of his own inſtead, by which, as he ſtates it, the reſult will be very different, and according to which he ſays they will be found to have gone within the limits of the act. In anſwer to theſe repreſentations, I ſhall firſt explain the grounds of my method of calculation, and juſtify the propriety of it, and ſhall then anſwer his objections, ſhew the impropriety of his method of calculation,

point out how little it would ſerve his turn in the preſent inſtance, and that it would have anſwered the purpoſe ſtill leſs in the two former trials of theſe watches.

The act of parliament makes no mention of a rate of going of time-keepers; therefore the allowance of a rate is an indulgence, and the commiſſioners might either require the watch-maker to adjuſt the watch to keep mean time accurately, or to declare its daily rate by which he would abide during the trial of it. But it is certainly a more eligible way to deduce the rate of the watch from its going during its trial, under the direction of the commiſſioners, than to take it from the watch-maker's declaration, or to require it to be adjuſted perfectly by him, on account of the difficulty which he may labour under either to adjuſt it exactly, or to give its true rate of going, for want of the uſe of an Obſervatory, or a ſufficient ſkill in deducing time from aſtronomical obſervations. Beſides it ſeems proper that the commiſſioners ſhould know from what obſervations, and in what manner the rate made uſe of was deduced.

A rate of going then being allowed, it remains to conſider for what ſpace of time the time-keeper ought to be compared directly with the heavens by aſtronomical obſervations, or elſe with a clock continually corrected by them for this purpoſe.

purpoſe. The ſpace of time employed to aſcertain the rate ſhould be long enough to prevent ſmall errors therein, ariſing from the unavoidable minute errors of the obſervations influencing the calculations of the going of the watch when extended to ſix months, by more than a few ſeconds; and it ſhould not be very long, as 3, 4, 5, or 6 months, becauſe the time-keeper may be liable to alter its rate of going in ſuch a length of time; therefore the rate ſhould be taken from ſome moderate ſpace of time, ſuch as the firſt month of the trial, as being moſt likely to ſuit the ſubſequent going of the watch, and conſequently the moſt proper to be made uſe of on the occaſion. Another reaſon for uſing a rate deduced in this manner is, that perſons going to ſea will ſeldom be able to get their time-keepers either finiſhed or repaired by the watch-maker ſoon enough to be able to get trials made of their rate of going for a longer time than a month; I have found by experience, that they have often been forced to be contented with a much ſhorter trial of the rate, and ſometimes only of a few days. Therefore the deducing the rates of watches from the going during the firſt month, in public trials at the Royal Obſervatory, in order to apply it to their ſubſequent going, is analogous to the manner in which they are likely to be put to uſe when ſent on voy-

ages

ages to ſea; which fully proves the propriety of the method. A third reaſon in favour of this method is, that it is a very fair one, and therefore proper to be adopted as a general principle, becauſe it is made without any conſideration whether the rate ſo reduced from the firſt month ſhall be more or leſs favourable to the watch than any other rate that might be deduced from the trial of the watch.

Further, this method was attended with this advantage, that from a twelve months trial of a watch, I could deduce the errors of the watch in ſix different periods of ſix months each, whereby the commiſſioners might be enabled to form a better judgment what dependence might be placed on the watch in voyages at ſea, and infer how far it afforded a uſeful and practicable method, which is the main intent of the act of parliament, and ſhould never be loſt ſight of, according to the words of it recited in every nautical almanac, which ordain that ſuch rewards ſhall be due and paid "ſo ſoon as the ſaid com-"miſſioners, or two thirds of them at the leaſt, "ſhall, after ſuch experiments and voyages have "been made and performed as aforeſaid, have "declared and determined that ſuch method is "generally practicable and uſeful, and ſufficiently "exact to determine the longitude at ſea within "the degrees or limits aforeſaid, in all voyages

"for

" for the ſpace of ſix months (impediments from " cloudy and hazy weather excepted)."

Laſtly, this method was long ago ſanctioned by the authority of the Board of Longitude in the caſe of Mr. Harriſon's ſecond voyage with his watch to the Weſt Indies, that to Barbadoes. The trial on the firſt voyage to the Weſt Indies, that to Jamaica, had been rendered nugatory, for want of the rate of the watch having been previouſly ſettled by aſtronomical obſervations before the voyage. Mr. Harriſon had never mentioned any rate of going of the watch before the voyage; yet, on his return from Jamaica, he claimed the allowance of a rate, which he deduced from nine days obſervations of equal altitudes of the ſun made at Portſmouth, previous to the voyage, which however had been only made in order to compare the watch with the time of the meridian of Portſmouth, and by no means with a view to determine the rate of the watch, for which laſt purpoſe they were not judged accurate enough, or continued long enough, though abundantly ſufficient to determine the firſt point, namely, how much the watch differed from the time of the meridian of Portſmouth, and to ſet it thereby. Diſputes having ariſen about the allowance of a rate to the watch, between Mr. Harriſon and the commiſſioners, in order to ſettle the matter the

voyage

voyage to Barbadoes was reſolved on. It was in conſequence propoſed by the commiſſioners to Mr. Harriſon to ſend his watch to the Royal Obſervatory at Greenwich, to have its rate of going determined there by Mr. Bliſs, then Aſtronomer Royal, by one month's compariſon with aſtronomical obſervations, before the voyage; to which Mr. Harriſon at firſt conſented: he afterwards however objected to it, and requeſted the Board, that they would allow him to declare the rate of going of the watch himſelf, which he would abide by in the voyage; which the Board agreed to. Mr. Harriſon deduced the rate from a compariſon of his watch with the aſtronomical clock ſet up in a temporary obſervatory at Portſmouth, and corrected by aſtronomical obſervations made by Mr. John Bradley, nephew to Dr. Bradley, who was appointed to compare the watch with the meridian of Portſmouth before Mr. Harriſon ſhould ſet out on the voyage to Barbadoes, as alſo to make obſervations of the eclipſes of Jupiter's firſt ſatellite, correſpondent to thoſe that might be made by myſelf and Mr. Charles Green at Barbadoes, whither we had gone before, in order to determine the longitude of Barbadoes with reſpect to Portſmouth, to be compared with what ſhould be found to reſult from the obſervations we ſhould make of the difference of the time of the watch from that of the meridian of Barbadoes, on its arrival there. See the minutes

of the Board of Longitude, of Auguſt 17th 1762, and Auguſt 4th 1763, relative to this matter. It is obvious that whether the rate of the watch was ſettled from a trial at Greenwich, or by Mr. Harriſon from other obſervations made at Portſmouth, though not communicated to the Board of Longitude, it was equally a rate ſettled from obſervations previous to the voyage, in order to be made uſe of in the ſubſequent trial. Moreover, I have generally made uſe of a rate ſettled in this manner myſelf, as appears from my reports to the Board of Longitude, concerning the three ſeveral trials of Mr. Mudge's two time-keepers, and of Mr. Arnold's time-keeper, in 1779, in all which I made uſe of the rate of going deduced from the firſt month of the trial, except in the firſt trial of the two time-keepers, *viz.* in 1779; in which I took the mean rate of the firſt forty-one days; which, however, makes no difference in the principle of the method.

I now proceed to the conſideration of Mr. Mudge's objections to the method I have uſed in calculating the going of the time-keepers, and of the method he propoſes to ſubſtitute in its ſtead. His objections to my method of calculation are, that it is unfair and arbitrary, and different from that which I uſed in the trial of Mr. Harriſon's watch. I flatter myſelf, I have already, in explaining the grounds and reaſons of my method,

ſhewn, that it is not unfair or arbitrary, by pointing out, that the act of parliament makes no mention of a rate, and that the allowance of a rate is an indulgence; that a rate deduced from a month's trial is abundantly ſufficient for uſe, during a ſubſequent trial of ſix months, and probably more favorable to the watch, and at the ſame time better adapted to practice, than a rate deduced from a longer ſpace of time; and alſo that my method of calculation gives conſiderable information concerning the nature and qualities of the watch, was ſanctioned long ago by the precedent of the Board of Longitude, in the caſe of Mr. Harriſon's ſecond voyage with his watch to the Weſt Indies, and has been generally uſed by myſelf.

But Mr. Mudge ſays, that in calculating the going of his watches, I have made uſe of a very different method from that which I uſed in the trial of Mr. Harriſon's; that I there fixed upon its going in periods of equal length, immediately ſucceeding each other, as the proper method of determining its accuracy; and that I ſhewed, that the difference in the going of a time-keeper, in ſucceſſive periods of equal length, conſtitutes its actual error; and that I fixed upon periods of ſix weeks for Mr. Harriſon's watch, becauſe a voyage of ſix weeks was the time limited by the act of Queen Anne, under which Mr. Harriſon

claimed his reward. But as the preſent act has required the ſame degree of perfection in a voyage of ſix months, as was before required for one of ſix weeks, as to his father's time-keepers it became neceſſary to make the compariſon between periods of ſix months inſtead of ſix weeks; and that if the ſame method had been uſed with his watches as with Mr. Harriſon's, it will be found they have clearly gone within the limits of the act.—To this I anſwer, that I compared the going of Mr. Harriſon's watch in each period of ſix weeks with its going in the preceding ſix weeks, rather than with its going in the preceding month, or in the firſt month of the trial, becauſe it afforded a more convenient and eaſy mode of calculating the errors of the watch, by a ſimple ſubſtraction of the going in one period from that in the other, intelligible to every-body, and not unfavorable to the watch, but rather the contrary; and yet ſufficient to juſtify the main concluſion I deduced from the trial, namely, that the watch could not be depended upon to keep the longitude within a degree, in a Weſt India voyage of ſix weeks; whereby I juſtified the commiſſioners in their former reſolutions concerning the watch. There was no need for me to enter into a diſpute with Mr. Harriſon about the rates of going of his watch,

when this method, which I thought he could not object to, as being favorable to him, was ſufficient to prove the imperfection of his watch. Mr. Harriſon, however, objected to this calculation, and propoſed the very method which I have now uſed in the caſe of Mr. Mudge's watches, and which Mr. Mudge objects to. A period of ſix weeks going was proper to compare with the going of the watch in the ſucceeding ſix weeks, and ſo would a period of a month have been; but it does not appear that it was improper, or leſs proper to compare with the going of the watch for a greater length of time, ſuch as ſix months, the period of an Eaſt India voyage. Mr. Harriſon's was a particular caſe, very different from Mr. Mudge's; ſimilar modes of calculation could not therefore be adopted, with any degree of propriety; as I have ſhewn before. In my account of the going of Mr. Harriſon's watch I did not lay down any general principle, that the time uſed in aſcertaining the rate of the watch ſhould be equal to the length of the ſubſequent trial of it; for I confined myſelf ſolely to the conſideration of Mr. Harriſon's caſe. Therefore Mr. Mudge's concluſion, that it was neceſſary a compariſon ſhould be made between periods of ſix months, in the caſe of his time-keepers, does not follow from any premiſes which I have laid down, as

Mr.

Mr. Mudge endeavours to make his readers believe.

Neither does it follow neceſſarily from analogy, becauſe it was proper to compare the going of Mr. Harriſon's time-keeper in ſucceſſive periods of ſix weeks together, that it would, therefore, be proper to make compariſons between periods of ſix months with Mr. Mudge's time-keepers; for inferences from analogy have not the force of direct demonſtrations, and do not neceſſarily hold, and cannot be fairly drawn at all, without an attentive conſideration of the different circumſtances of the different caſes. I have ſhewn before, from a conſideration of the various circumſtances concerned in the different methods of calculation, that the method of calculating the going of a watch, from the rate of the preceding month, is a fairer and properer method than from the preceding period of ſix months.

Mr. Mudge, from page 20 to 22, from ſomething which he calls reaſoning, but which does not appear to be very intelligible, endeavours to ſhew, that a mean daily rate of a time-keeper ought to be taken from a large portion of time, and applied to a ſmall one; or at leaſt taken from a period equal to that it is intended to be applied to. He obſerves, for inſtance, that a mean daily rate taken from ſix weeks is very proper to be uſed as a ſtandard of allowance for

the

the ſucceeding week; and that, on the contrary, the mean daily rate of one week would be very improperly applied as a ſtandard for a daily allowance during the following ſix weeks. His argument, as far as I can trace a ray of light through the darkneſs of his laboured explanation, ſeems to depend on a principle frequently adopted in experimental philoſophy, and no doubt very proper in common caſes, that it is unſafe to deduce a large quantity from a ſmall one, leſt the unavoidable ſmall errors of the leſs quantity ſhould affect the larger more than the leſs, in proportion as it exceeds the other; and on the contrary, that it is advantageous to deduce a ſmall quantity from a large one, becauſe the unavoidable ſmall errors of the large quantity may be expected to affect the ſmaller quantity leſs than the larger, in proportion as it is leſs than the larger.

In order to form a judgment whether this principle juſtifies Mr. Mudge's poſitions, I muſt obſerve that the uncertainty of the daily rate of the watch, whether deduced from the firſt month or firſt ſix months, will ariſe either from errors in the aſtronomical obſervations, by which the going of the watch is computed, or from irregularities and fluctuations in the rates of the watch, which in ſmall ſpaces of time may run one way, and in longer times, by their very variations and oppoſite tendencies, may in ſome meaſure correct one another.

another. The firſt cauſe of error in the computed rate of a watch, that ariſing from the ſmall errors of the aſtronomical obſervations, can be but trifling in good obſervatories, as the whole variation of the watch in the interval uſed to ſettle the rate, whether it be a month or ſix months, would not be affected thereby by more than half a ſecond, or at moſt a ſecond, if deduced from only two aſtronomical obſervations, one made at the beginning and the other at the end of the interval; and conſequently the error in the computed going of the watch in ſix months, if deduced from the going of only one month, would not exceed ſix times thoſe quantities, viz. 3″ or 6″, which are of no conſequence in practice; but if the daily rate of the watch be taken as uſual from a mean of the daily rates of the ſeveral days, it will be obtained more exactly, and the error reſulting on the computed going in ſix months will be ſtill ſmaller.

As to the ſecond cauſe of error in the daily rate of a watch, that owing to the irregularities and fluctuations of the rates, from a mean of which the rate propoſed is deduced; it remains to be conſidered whether this is likely to prevail moſt, when the interval made uſe of to ſettle the rate is one month or ſix months. Mr. Mudge maintains the latter, without however giving any clear and incontrovertible proofs of it. His argument ſeems to depend on a ſuppoſition, that the ſpace of one month is not ſufficient for the watch to run through

through the periods of its irregularities, but that ſix months are. I muſt own that I cannot ſee the grounds of this ſuppoſition, ſince we are too little acquainted with the various mechanical cauſes which may affect watches with irregularity (cauſes fortuitous and vague in their nature, and not defined as to their quantities and modes of operation) to be able to make any computation either of the errors they may produce, or of the returns of them, or even to gueſs at them. A knowledge of this kind will, I fear, for ever elude the reſearches as well of the philoſopher as the watch-maker. Such vague conſiderations as theſe cannot be admitted in a method of determining the longitude, which is required to be generally practicable and uſeful. One of the errors, to which moſt time-keepers hitherto made have been found liable, and particularly Mr. Mudge's, that of their accelerating or retarding their rates of going after a length of time, or the want of a permanency in their rates, is particularly adverſe to the principle of taking the rate of a watch from a long ſpace of time previous to the intended trial, leſt the rate may have become changed for another very different one.

Being perſuaded, from the reaſons before given, that Mr. Mudge's principle of taking the rate of a watch, from a period of time equal to that of the going afterwards, was not a juſt one, I have taken the

the trouble to examine the matter by ſome particular calculations, by comparing the going of his time-keepers, during the late trial, in forty-one periods of ſix weeks, with their going in each preceding period of ſix weeks, and alſo with their going in each preceding week, and have given the reſult in N° XVI. of the Appendix; by which it appears that the rate deduced from the going of the preceding week agreed a little better at a medium with the actual going of the watch Blue, and a little worſe with the actual going of the watch Green, than the rate deduced from the preceding ſix weeks did; the ſum of the errors, by uſing the rate of the preceding week, being to the like ſum, by uſing the rate of the preceding ſix weeks, as 18′. 11″ to 19′. 27″ with the watch Blue; and as 40′. 55″ to 37′. 45″ with the watch Green. Although a period of a week would be generally thought too ſhort to deduce an accurate rate from, yet it appears to have anſwered nearly as well in theſe calculations as a period of ſix weeks; its cloſer connection with the ſubſequent period of ſix weeks, to which it was applied, making amends for the inexactneſs ariſing from the ſhortneſs of the interval. Hence we may conclude, that a rate deduced from the previous trial of a month, would probably agree much better with the going of a watch in the ſubſe-

ſequent ſix months, than a rate deduced from a previous trial of ſix months. The period of a month ſeems, from inſpection of the daily rates, to be a ſufficient allowance for the variable irregularities of the going of the time-keeper to range in.

Mr. Mudge's method of finding the error of the watch in ſix months, by taking the difference of the whole accelerations or retardations of the watch in two ſucceſſive periods of ſix months, is what, I believe, nobody would have thought of but himſelf; nor do I think that he or any other artiſt would chuſe to be bound by it in future trials. There is an obvious objection to it, that if the watch ſhould not be perfectly regulated to go at the ſame rate in all the degrees of heat and cold, to which it may be expoſed during the return of the ſeaſons, which is a moſt difficult thing to accompliſh, and one of the periods of ſix months ſhould include all the hotteſt part of the year, and the other all the coldeſt, ſome difference might ariſe from that cauſe; and by conſpiring with the other irregularities of the watch might produce a conſiderable error in the reſult. Mr. Mudge's method appears to be improper, on another account, at leaſt conſidered as a mode of trial for the information of the commiſſioners, to enable them to form a judgment upon its uſefulneſs, that it ties

us down to a ſingle calculation, which can give but little information concerning the ſteadineſs or unſteadineſs of the going of the watch in the courſe of the twelve months trial; while my method clearly aſcertains that point. I have before ſhewn that it would be ſeldom practicable to obtain ſo long a trial as that of ſix months previous to the ſending a watch to ſea. Laſtly, the watches being ſubject to have their rates of going accelerated or retarded after a length of time, ſo as not to return back to their firſt rate, it may happen that the mean rate of going in the ſecond ſix months may be conſiderably different from that in the firſt ſix months.

I ſhall illuſtrate the laſt remark by examples taken from the trials of Mr. Mudge's watches at the Royal Obſervatory. The firſt time-keeper got 5′. 35″ in half a year, between November 11th 1776 and May 12th 1777; and it got 11′. 10″ in the next half year, between May 12th and November 10th 1777; the difference is 5′. 35″, the error of the time-keeper in ſix months, according to Mr. Mudge's method. In the firſt trial of the two time-keepers Green and Blue, the watch Green got 1′. 12″ in half a year between May 31ſt and November 30th 1779; and it got 7′. 0″ in the next half year, between November 30th 1779 and June 3d 1780. The difference is 5′. 48″ for the error of the time-

keeper in ſix months. The watch Blue in the ſame firſt half year got 0′. 35″, and it got 28′. 16″ in the next half year; the difference is 27′. 41″ for the error of the time-keeper in ſix months. In the ſecond trial of theſe time-keepers, the watch Green got 1′. 8″ in half a year, between Auguſt the 20th 1783 and February 20th 1784; and it got 6′. 53″ in the next half year, between Feb. 20 and Aug. 21, 1784; the difference is 5′. 45″ the error of the time-keeper in ſix months. The watch Blue, in the ſame firſt half year, got 7′. 2″, and in the ſecond half year it got 12′. 30″; the difference is 5′. 28″ for the error of the time-keeper in ſix months, according to Mr. Mudge's method. We now come to the laſt trial of theſe time-keepers, that in 1789 and 1790. It is with reſpect to this that Mr. Mudge ſays, p. 19, that if the ſame method of calculation had been uſed, as I had adopted in the caſe of Mr. Harriſon, the reſult would have been very different from what I found; and it would have been manifeſt that the terms of the act had been moſt fully complied with. Accordingly he ſays, p. 25, that it appears from my regiſter, that the watch called Green during the firſt ſix months gained 1′. 41″, 21; and during the laſt ſix months gained 3′. 39″,79; ſo that the difference between the two periods is 1′. 58″,58, which is within the ſtricteſt limit of the act; and the watch

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called Blue, during the firſt ſix months loſt 4′. 10″,04, and during the laſt ſix months loſt 0′. 14″,56; ſo that the difference between the two periods is 3′. 55″,48, which is within the moſt extended limits of the act.—For theſe ſeveral numbers ſee N°. IV. to X. of the Appendix.—Hence he concludes that both the watches went within the limits of the act.

It is obvious to remark that the watch Blue, according to this calculation of Mr. Mudge, only went within 4½″ of 4′, the moſt extended limit of the act; and as the act requires two watches to be tried at the ſame time, the other, viz. the watch Green, having gone much nearer, and even within the neareſt limit of the act, according to Mr. Mudge's calculation, could be of no ſervice to him, even ſhould the watches have been ordered on further trials, and have gone as well under them as in this firſt trial of them; ſince both the watches muſt be judged by that which went the worſt; becauſe the commiſſioners could not declare that the method afforded by the time-keepers was more exact than what was indicated by that watch which erred the moſt. It appears then to be only for this ſmall difference of 4½″ that Mr. Mudge has made all this mighty ſtir, and introduced a new, inconvenient, improper, and not generally practicable method of computing

computing the going of time-keepers. Is it not highly probable that, if this watch had been ordered on further trials by the commiſſioners, it might have gone worſe than on this by $4\frac{1}{2}''$ in ſix months? eſpecially conſidering that the winter, during which the time-keepers were tried, was remarkably temperate, the thermometer in the tranſit room at noon having never ſtood lower than 36°; whereas the ſeaſon was much ſeverer during the trial of Mr. Harriſon's watch in the ſame room, the thermometer at noon having once deſcended ſo low as $25\frac{1}{2}°$.

Theſe ſuppoſitions are confirmed by a fact relating to the other watch Green, that which went the beſt of the two, and even within the neareſt limit of the act at the end of the trial, according to Mr. Mudge's calculation; which at the ſame time overturns all Mr. Mudge's pretences, that both his time-keepers had gone within the limits of the act. The fact is this, that by taking the rate of its going from the firſt ſix months of the trial, and applying it to correct the going in the ſecond ſix months, which is Mr. Mudge's method, the watch did not keep time within four minutes of time during the whole of the ſecond ſix months. Mr. Mudge may ſay, if he pleaſe, as he has ſaid before, that I have contrived to make ſuch calculations as to make it appear, that the watch had erred be-

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yond *any* of the limits of the act. This, however, I do assert, and will now prove, and thereby shew that I have contrived fair and proper calculations to disprove his assertions upon his own principles. It will appear by comparing the sums of the daily rates of this watch, in N° IX. of the Appendix, that between June 24th and Dec. 24th 1789, or in 183 days, it got 1′. 41″,21; and between Dec. 24th 1789, and May 6th 1790, which (considering that the watch was stopped five days) makes a space of 128 days, it got 5′. 13″,28. But it ought to have got only 1′. 10″,79, according to the tenor of its going in the first six months: for if 183 days give a gain of the watch 1′. 41″,21, then 128 days ought, by the rule of three, to give a gain of 1′. 10″,79, which differs from 5′. 13″,28, the actual gain of it, by 4′. 2″,49, or 2½ seconds beyond the most extended limit of the act, which requires the method of finding the longitude by a time-keeper to be generally practicable and useful, and sufficiently exact to determine the longitude at sea within certain limits in all voyages, for the space of six months, impediments from cloudy and hazy weather excepted.

Mr. Mudge, in p. 29 and 30, has proposed two other methods of ascertaining the going of time-keepers, in addition to his former one, which I have

have already conſidered, viz. to take a mean of the leaſt and greateſt daily rates of going of a watch during the whole year, or to take the mean daily rate deduced from the going for the whole year, to be allowed for upon any one or more periods of its going within the year, let their extent be what they may.—The firſt method ſeems prepoſterous, to take ſo important an element of the calculation from the two worſt goings of all, eſpecially if it be conſidered that an error of only one ſecond in the aſſumed daily rate will produce an error of three minutes in the computed going of the watch in ſix months. The laſt method is very favorable to himſelf, becauſe let the watch go ever ſo ill, it will juſt take off half the error. Both methods are liable to this inſurmountable objection, that they are impracticable in the caſe of a ſea voyage, becauſe the propoſed rate could not be known till the voyage was over, and conſequently could be of no uſe in the voyage. The latter method might be uſeful in ſettling the longitudes of places ſeen or touched at during the voyage, for the improvement of geography; but that is not the longitude now in queſtion.

It is ſo ſtriking one cannot avoid remarking Mr. Mudge's *curious* inconſiſtency in finding great fault with me, p. 26, for uſing two different methods of calculating the going of time-keepers, though

though on two very different occaſions, namely the trial of Mr. Harriſon's watch, and the late trial of his own watches, and at the ſame time making uſe himſelf of three different methods in one and the ſame caſe, the late trial of his own watches. The time-keepers ought indeed to be good enough to bear all the different methods of calculating their going, which might be of uſe on different occaſions: Mr. Mudge only ſhews his ſenſe of the imperfection of his time-keepers by endeavouring to withdraw them from my method of examining them.

Mr. Harriſon ſaid, at the diſcovery of the principles of his watch, that as ſoon as it is put together, it will ſhew its rate of going in three hours accurately, the ſame which it will keep afterwards; ſo that he can ſoon determine it by compariſon with his pendulum clock. See the principles of his time-keeper, with plates of the ſame, which I publiſhed for the Board of Longitude in 1767. But Mr. Mudge will not allow us to know the rates of his watches till they have been going and tried ſix months. A ſtrange difference this, in the opinions of theſe two artiſts, or in the properties of their watches! and yet Mr. Mudge inſiſts on it, that his watches are conſiderably ſuperior to Mr. Harriſon's, which I allow they are. This ſhews that he has not a very

good opinion of his watches, to require ſo long a trial of them to ſettle their rate.

After all, I have only uſed, extended, and explained the method of calculating the going of time-keepers, which I found in uſe when I began to try them. But I do not pretend to give laws to the public. The more enlightened of the preſent age will examine the various methods that have been propoſed, and weigh the arguments produced in favour of each, and will judge for themſelves. Other time-keepers, of very different conſtructions from the preſent, may be invented hereafter, which may ſuggeſt and juſtify very different modes of trial and calculation. In the mean time I am not under any apprehenſion that the leaſt injuſtice has been done to Mr. Mudge, or any other makers of time-keepers, by the application of the methods of calculating their going to them which I have uſed my beſt endeavours to explain in this anſwer.

There is another method of examining the going of time-keepers, which ſome perſons may think preferable to that which I made uſe of; which I ſhall therefore deſcribe. It is by correcting the going of the watches in the ſeveral periods of ſix months, by the mean rate deduced from the month immediately preceding each period,

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inſtead of correcting their going in the ſeveral periods by one and the ſame mean rate, that deduced from the firſt month at the commencement of the trial. Mr. Mudge, indeed, has taken no notice of it, becauſe it would not anſwer his purpoſe; for though the errors of the watches are a little reduced by it, yet they ſtill far exceed the limits of the act of parliament, as appears by the reſult of this method, which I have given at N° XV. and XVI. of the Appendix. My reaſon for not adopting this method, inſtead of the other, was this, that it cannot be expected that all perſons, who carry time-keepers to ſea, ſhould have ability, nor, if they had ability, always time, to determine the rate of going of their watches by a month's trial before they went to ſea; and conſequently that this method could not be conſidered as generally uſeful and practicable.

Mr. Mudge, in p. 31 and 32, makes mention again of the regularity of the going of his firſt time-keeper in the hands of Admiral Campbell, during the two voyages to Newfoundland, and thinks that this, as well as the better going of the two laſt time-keepers in the hands of Mr. Dutton [after the cloſe of my trial of it] than in mine, may induce moſt perſons to believe that I have been unfriendly to the ſucceſs of the time-keepers.—I have already, from p. 66 to 75,

made ſufficient remarks on his arguments in favour of his time-keepers from Admiral Campbell's trial of the firſt in his two voyages to Newfoundland. I am informed from Mr. Dutton, that the time-keepers were tried in his ſhop, which is a cloſe room, where there is a ſtove occaſionally lighted in winter; whereas there is no fire place in the tranſit room at the Royal Obſervatory, nor is there ever any fire made there. Moreover the air of London out of doors is generally ſome degrees warmer than at Greenwich. This difference of circumſtances alone might occaſion a conſiderable difference to cauſe the time-keepers to go better with Mr. Dutton than with me. However, notwithſtanding this advantage in their favour at Mr. Dutton's, I find by a calculation of their going during his trial of them, ſee N° XI. and XII. of the Appendix, that the watch Green went worſe with him than with me, its greateſt error with him having amounted to 8′ 12″ in ſix months, whereas with me it did not exceed 7′ 4″. On the other hand the watch Blue went better in his trial of it than in mine, its greateſt error with him having been 3′ 23″, whereas with me it amounted to 6′ 35″. The going of the watches with Mr. Dutton evidently corroborates my trial of them, as the going of the firſt time-keeper with Dr. Hornſby agreed with

with and corroborated my trial of it, ſee p. 35, 36, and 63 of this anſwer. In theſe calculations I have made allowance for the daily rates of Mr. Dutton's clock ſet down in p. 81 of Mr. Mudge's pamphlet, and the alterations of it, and the letting down the time-keepers one day, mentioned by the ſide of the regiſter.

Mr. Mudge endeavours to enhance the going of the time-keepers in Mr. Dutton's trial, which he miſtakenly ſuppoſed better than in mine, by obſerving, p. 32 and 92, that they were put immediately into Mr. Dutton's hands without cleaning, and that at the end of the trial they had been going more than three years without cleaning.—Mr. Mudge has precluded himſelf from any right to make uſe of this argument, becauſe he declined the offer made him by the Board to clean his watches previous to any further trial they might undergo; which ſhews he thought ſuch cleaning neither neceſſary nor uſeful. See p. 45 of this anſwer and page 11 of the Appendix. The watch Green was loſing 2″,3 in the laſt month of my trial of it, and was gaining 3″,8 in the firſt month of Mr. Dutton's trial, the difference is 6″,1; and in the laſt month of Mr. Dutton's trial it was keeping equal time, or going 3″,8 ſlower than in the firſt month of his trial. The watch Blue

was

was losing 0″,8 in the last month of my trial of it, and gaining 3″,1 in the first month of Mr. Dutton's trial of it, the difference is 3″,9; and in the last month of Mr. Dutton's trial of it got 2″ a day, or went 1″,1 slower than in the first month of his trial. These variations of the watches show they were not constructed upon such permanent principles as Mr. Mudge pretends. Such variations must be allowed to be of consequence, because an alteration of the rate of only 1″ in a day will make 3′ in 6 months. It does not appear that the letting down the watches and keeping them in that state should affect the rate of their going when they should be set in motion again; at least it has not had any such effect in the instances of their being accidentally let down at the Royal Observatory. It seems to follow that no such effect should take place with respect to Mr. Harrison's watch, from what he says in the principles of the same, quoted before in p. 105, that as soon as it is put together it will shew its rate of going in three hours accurately the same which it will keep afterwards.

I shall in this place take notice of the accounts of the going of the first time-keeper given in the two last pages of Mr. Mudge's pamphlet. The first contains Admiral Campbell's account of

the going of the watch on ſhore, at Newfoundland, in the courſe of three months and a half, in the year 1784, and of its going there again in the courſe of 4½ months in the year 1785, according to the Admiral's aſtronomical obſervations. I have given in N° XIII. of the Appendix an account of the daily rates of the ſame watch in 4½ month's trial of it by myſelf between November 11th, 1776, and March 24th, 1777, deduced from periods of a week, to reſemble as nearly as poſſible the intervals between the obſervations from which the rates were deduced by Admiral Campbell. It appears to have gone full as well in mine as in the Admiral's trials, that is to ſay, its daily rates have not varied more in mine than in his, notwithſtanding it was evidently in a ſtate of accelerating its rate of going continually more and more in my trial of it. I might add, that it is very probable Mr. Mudge, between the concluſion of my trial of it in 1778, and Admiral Campbell's trial of it in 1784, had made farther improvements or adjuſtments to it, to correct the tendency of the watch to continually accelerate its rate. The leaſt daily rate in this interval happened between December 2d and 9th, 1776, and was —0″,13; the greateſt between March 17th and 24th was + 3″,58; the difference is 3″,71. In Admiral Campbell's reſidence at Newfoundland in 1784, the leaſt daily

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rate between July 13th and 20th was —0″,03, and the greateſt, between Auguſt 17th and 21ſt was + 2″,07; the difference is 2″,10. In the Admiral's reſidence at Newfoundland in 1785, the leaſt daily rate from September 2d to 4th was —2″,70, and the greateſt, from Auguſt 8th to 10th, was + 1″,25; the difference is 3″,95. The greateſt variation by my trial is 3″,71 which is greater than 2″,10 the firſt, and leſs than 3″,95 the ſecond of theſe errors.

The laſt page of the pamphlet contains the longitudes of Newfoundland and Oxford found by the time-keeper. I have already ſhewn, p. 72, that the longitude of Newfoundland determined by Admiral Campbell in the year 1784, when properly corrected, differed 41″ from the true longitude in going out, and 34″ in the return. The longitude determined from the voyage of 1785 is ſet down, differing 24½″ in going out, and 21½″ in the return, from the true longitude. But I do not know upon what calculations they depend. See p. 73 of this anſwer. All this is very reconcilable with the going of the watch during an equal time in my trial of it in 1776 and 1777, as I have ſhewn in p. 75. The longitude of Oxford, determined by the time-keeper, differs from 0″,6 to 1″,2 from the true longitude. This ſhews the great uſefulneſs of a good time-keeper in determining the longitude of places

not

not very diſtant from one another, or in ſhort journeys or voyages; and is no more than what might be expected from the frequent near agreement of the daily rates on ſucceſſive days. The like advantage has been found from Mr. Arnold's, Mr. Emery's, and Mr. Earnſhaw's time-keepers. The longitude of the Royal Academy at Portſmouth was determined, April 21ſt, 1774, by a watch of Mr. Arnold's, to be 4′. 26″, and on May 29th, 1775, by another watch, to be 4′. 26″, and Auguſt 11th, 1791, to be likewiſe 4′. 26″, by a watch of Mr. Earnſhaw's, weſt of the Royal Obſervatory at Greenwich in time. Its true longitude by various aſtronomical obſervations is 4′. 25″, as ſet down in the requiſite tables.

Mr. Mudge finds fault with me in p. 32, for only ſaying, when the watches ſtopped in January 1790, that they ſeemed to have ſtopped for want of being wound up, and for not ſaying, as I did in a regiſter publiſhed ſome years ago of the going of a watch of Mr. Arnold's [in 1779] the watch went down having been forgot to be wound up. I have given an account of this matter in p. 41 and 42 of the hiſtory of the watches. The reaſon of the difference of my remarks in the two caſes was, that the aſſiſtant in the caſe of Mr. Arnold's watch had poſitively ſet down in the regiſter, that the watch went down, having been forgot to be wound up, which he may have known by counting the

turns taken to wind it up; and in the other caſe no ſuch remark was made, the watches having been wound up before any notice was taken of their being ſtopped.

Mr. Mudge, from p. 35 to 42, has given an account of what he ſuppoſes paſſed at the Board of Longitude on June 11th, 1791, when they were ſitting on his memorial; for he was never introduced to the Board; but which he may be ſuppoſed to have been informed of in the whole, as he acknowledges he was in part, by a member of the Board, who has always been his warm advocate. I am glad he has always had an advocate there, becauſe it ſhews that no reſolutions were taken concerning his watches without mature conſideration. The whole of what he has attributed to me, as having ſaid concerning the time-keepers, is ſo very proper and commendable for me to have ſaid, that though I took no notes, not expecting to have my words ſo minutely reported without doors, I ſhall ſay nothing to extenuate this charge, but rather to add to it. I have already, at p. 51 and 52, given an account of what was ſaid at the Board, relative to the propoſal for purchaſing Mr. Mudge's two time-keepers, together with the ſecret of their conſtruction, at the price of £. 2,000, and therefore ſhall have occaſion to ſay leſs here.

I kept

I kept the regiſter publiſhed under the ſanction of the Board of Longitude, of the going of Mr. Arnold's watch in 1779 and 1780, which he allows to be very accurate; while his two time-keepers, which were then tried alſo for the firſt time, went very indifferently, as I have already ſhewn at p. 37 and 76. I have no apprehenſion that any body will join Mr. Mudge in opinion, that the teſtimony of an Aſtronomer Royal, and of myſelf in particular, is leſs deſerving credit and reſpect than that of any other perſon whatſoever. Neither do I apprehend that my having been then on friendly terms with Mr. Arnold will diminiſh the credit of my report of the going of his watch. My acquaintance with him was founded on a regard for his abilities, and the unwearied pains he took for many years to produce uſeful inventions, and to execute time-keepers in great numbers for the uſe of the public. I firſt found out his merit, and recommended him to the Board, by whoſe encouragement and rewards principally he has been enabled to bring his time-keepers to their preſent degree of perfection, ſuperior in ſimplicity and readineſs of adjuſtment to Mr. Mudge's, as well as in exactneſs of going, and conſequently more likely to be uſeful. He adds, that Mr. Arnold has ſince quarrelled with me, and as a candidate for the rewards of the act had other time-keepers under trial in my hands,

which have not gone, according to my account, at all within the limits of it.—Mr. Mudge is very bold in his aſſertions here, as well as in many other places of his pamphlet, and equally miſtaken; for no time-keepers of Mr. Arnold's, as a candidate for the ſpecific rewards of the act of parliament, were ever tried at the Royal Obſervatory.

Mr. Mudge ſays, it is ſingular, if this watch [of Mr. Arnold's tried at the Royal Obſervatory in 1779 and 1780] is conſtructed upon principles that can be depended upon, that no ſecond has in the courſe of ten years been made like it, ſo as to entitle the inventor to claim the reward offered by parliament.—It is rather ſingular that Mr. Mudge ſhould make ſuch a remark, and be ignorant, notwithſtanding I mentioned it to the Board, and matters of leſs conſequence were reported to him, that a pocket watch was made by Mr. Arnold for Mr. Everard, of Lynn, and tried by him in a continued ſeries for four years and four months, from November 11, 1785, to March 25, 1790, which went ſtill better than that which I tried at the Royal Obſervatory in 1779 and 1780; beſides which, the regiſter of its going for the firſt two years of the time was publiſhed long ago by Mr. Everard, and diſtributed pretty freely by him; and the regiſter of its going for the whole time was publiſhed above a

year ago by Mr. Arnold, which Mr. Everard in a late letter to me certifies as authentic. However, Mr. Arnold could not obtain the rewards of the Act for the going of theſe two time-keepers, becauſe they were not tried both together at the Royal Obſervatory for the ſpace of a twelvemonth, and then afterwards in other voyages and trials appointed by the Commiſſioners. I deſire to mention, for the information of thoſe who may not be acquainted with Mr. Everard, that he is an eminent wine-merchant, of Lynn, in Norfolk, and a gentleman of fortune and great reſpectability; that he is furniſhed with a good pendulum clock made by Mr. Arnold, and a good tranſit inſtrument made by the late Mr. Siſſon; and that he is ſo fond of the accuracy of his watch, that he makes a point of attending every day to obſerve the tranſit of the ſun for aſcertaining the going of that and his clock.

The laſt charge brought againſt me, p. 40, is, that I mentioned to the Board, that Mr. Emery made the compenſation pieces for heat and cold of the two time-keepers for Mr. Mudge. He ſays that he could not do it himſelf in the country, without a great deal of trouble, for want of proper conveniencies, and therefore Count Bruhl got it done for him in town by Mr. Emery, as a good workman, and that this was no more than ſoldering two metals together.—If it was no more, it

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is rather ſtrange Mr. Mudge could not execute ſo eſſential a part of the watch himſelf, though in the country. That this was a very important part of the time-keepers, may be inferred from what Mr. Dutton told me long ago, that Mr. Mudge had been put to a good deal of trouble in conſtructing this very part of his time-keepers, becauſe he did not think proper to put it in the balance, Mr. Arnold having already done it in his. Mr. Emery has lately informed me, the compenſation pieces for heat and cold, originally put by Mr. Mudge in his time-keepers, did not anſwer, from having been made of bad metals; but that he had himſelf invented a particular kind of metal, which he made uſe of in conſtructing this part of Mr. Mudge's watches. This he did to oblige Count Bruhl, though he might ſeem to be acting againſt himſelf. In page 42, Mr. Mudge ſays, that I ought to have given a candid and unequivocal account of all I knew relative to the invention, that the Commiſſioners might be enabled to come to a deciſion, with all the knowledge upon the ſubject which I was capable of communicating.—How inconſiſtent is this with his blaming me a little before for acquainting the Board with the aſſiſtance which Mr. Emery gave him in conſtructing the thermometer part of his watches? Having no well-grounded objection to make to my behaviour on this occaſion,

that

that he may not appear to have nothing to ſay, he ſays, I ought to have done what I really did, truſting, probably, that ſome of his readers might be ſo inattentive, as to believe his inſinuation of my having neglected my duty, in a caſe where I had been moſt vigilant to perform it.

In juſtice to Mr. Emery, I think it proper to obſerve, that he did not offer his two time-keepers to the Board for a public trial, till March 5th, 1791, and after Mr. Mudge's watches had been returned to him. I was deſired by the Board to aſk him ſome queſtions about them. Accordingly I aſked him whether his watches were made upon Mr. Mudge's principles? He anſwered, no. Whether he thought they would go better than Mr. Mudge's? He ſaid that he could not poſitively tell, for however ſanguine his hopes might be, he would not flatter himſelf too much, as he was not informed of the rate of going of Mr. Mudge's time-pieces. What account he had kept of their going? He anſwered, he had compared them with Count Bruhl's clock, and expected an account of their going from him. He was then adviſed by the Board to keep an account of their going againſt their next meeting. Theſe were the captious queſtions, with which I teazed and harraſſed him, according to Mr. Mudge's account. My reaſon for aſking him whether his watches were made upon Mr.

Mudge's

Mudge's principles, took its riſe from my knowing that he had formerly made a curious pocket watch for Count Bruhl, with the eſcapement of Mr. Mudge's conſtruction, and from my having ſome how or other taken it into my head, that Count Bruhl had obtained a communication from Mr. Mudge of other parts of the conſtruction of his watches for Mr. Emery to make uſe of on this occaſion. This notion of mine ſeems to have ariſen from my conſidering that Count Bruhl had always been a great patron of Mr. Mudge; and from ſomething which Count Bruhl had both ſaid to me, and publiſhed in the introduction to a pamphlet, containing three regiſters of his trials of the going of this watch, as if the watch had been made according to Mr. Mudge's conſtruction, and from my not being then ſo well apprized as I am at preſent, of Mr. Emery's merit as a good workman, and ingenious watch-maker, to make me ready to imagine him capable of executing a watch of ſuch excellence as this evidently appears to be, from Count Bruhl's trials of it, with the help only of Mr. Mudge's eſcapement, ſupplying himſelf, out of his own invention, the many other eſſential parts of a watch, nay more eſſential parts in the opinion of the principal makers of time-keepers. Count Bruhl's words, in the introduction above mentioned, are as follows: "The watch to which the regiſters refer,

"I have

" I have now the honour to lay before the public, " was executed by Mr. Thomas (it ſhould be " Joſiah) Emery, in imitation of the model of a " ſcapement invented by Mr. Mudge about " thirty years ago [about 1754]; which model he " made at my requeſt, in order that ſo valuable " an invention might be brought into more ge- " neral uſe. This watch was finiſhed towards " the concluſion of 1782, &c." Theſe words ſeem to imply that the eſcapement was the principal thing in the watch; and Count Bruhl has, I believe, conſidered this watch, from this circumſtance, as if it was Mr. Mudge's watch, executed by Mr. Emery; in which opinion, perhaps, he has been carried too far by his great attachment to Mr. Mudge, and not being ſufficiently apprized, that though the eſcapement may be the principal thing in Mr. Mudge's watches, as it was in Mr. Harriſon's, it may not be ſo in other watches of different conſtructions, and certainly is not ſo in thoſe of Mr. Arnold and Mr. Earnſhaw. This is the eſcapement, which Mr. Mudge, p. 47, mentions, that the mechanical world have been obliged to him for freely communicating to them, and that it is one of the moſt conſiderable improvements made in pocket watches for a great many years; by which other watch-makers have been enabled to make watches far ſuperior to any they were uſed to make before. Notwithſtanding what is ſaid here,

I much queſtion whether this eſcapement was ever executed, to any purpoſe, by any perſon in this kingdom, beſides Mr. Mudge and Mr. Emery.

After the Board of March 5th, 1791, Mr. Emery, through the medium of a friend of mine, requeſted leave to call on me at Greenwich, to which I conſented. He then informed me that his buſineſs was to deſire to ſee my account of the going of Mr. Mudge's two watches. This I ſhewed him immediately, and he remarked that their going was not ſuch as to diſcourage his hopes of ſucceſs from his own two time-pieces. I then aſked him, as I had done before at the Board, whether the two time-keepers which he offered to the Board for public trial were made on Mr. Mudge's principles; to which he anſwered no, as he had ſaid before; but that Mr. Mudge was indebted to him for making the thermometer part of his laſt two watches for him. This circumſtance I afterwards mentioned to the Board, as related by Mr. Mudge.

Mr. Emery has ſince informed me, that he never ſpoke to Mr. Mudge, junior, in his life, nor ever exchanged three words with Mr. Mudge the father; that the model of Mr. Mudge's eſcapement was of a large ſize, being adapted to a clock; that he had a great difficulty to execute it of a ſmaller ſize, ſuitable to a watch; that it is

 very

very difficult to execute, but when once done will not be ſubject to wear out; that he had made two watches with the ſame eſcapement, for the king of France, from which models a watch had been made by Mr. Robin, a French watch-maker, which had come into his hands, and did not go better than a common watch, which he attributed to its not being well executed; that Mr. Mudge had executed his own eſcapement in a ſmall watch that he made for the queen, and that Count Bruhl had had an account of its going, which was not ſo good as that of the watch made by himſelf for Count Bruhl; that Count Bruhl told him lately that this watch went better than ever.

Mr. Emery has given me the following account of his making the watch for Count Bruhl, with Mr. Mudge's eſcapement. "About ſeven-
"teen or eighteen years ago, Count Bruhl re-
"peatedly urged me to make him a watch upon
"an eſcapement Mr. Mudge had invented; I
"for a long time ſucceſſively anſwered, that Mr.
"Mudge himſelf was the propereſt perſon for
"ſuch an undertaking; for, to own the truth, I
"doubted whether it would be poſſible to ever
"make a common ſized pocket watch with an
"eſcapement on ſo large a ſcale. But the Count,
"not contented with my repeated refuſal, at laſt
"prevailed on me. It was then he brought me

"a large frame, like a clock eſcapement, but at "the ſame time he gave me no rules concerning "it, nor any the ſmalleſt hint of the conſtruction "of Mr. Mudge's watch; nor did I ever ſee the "ſaid watch till many years after (for the Queen "had it) and his Majeſty himſelf did me the ho-"nour to ſhew it to me. I ſucceeded in this "undertaking pretty well; and I conceive that I "might be allowed to ſucceed, without any "helps, as different people are not always ſtruck "with the ſame ideas. Mr. Mudge being in "town ſome years after, the Count Bruhl would "have one of my watches pulled to pieces to "ſhew to him. This was done, and much ap-"proved of by Mr. Mudge, though himſelf "was then convinced that my watch was very "differently executed from that of his. I never "had an idea, the above circumſtance gave riſe "to the alluſion of my having copied from Mr. "Mudge, as Count Bruhl gave the ſame advan-"tage to every watch-maker as he did to me, "as he never wiſhed to deny any from ſeeing "the eſcapement; and I believe moſt of the pro-"feſſion did ſee it."

Mr. Emery ſays, that the two watches, which he preſented to the Board, had a different eſcapement from Count Bruhl's watch, and of his own invention. I think I have now vindicated Mr. Emery from the ſuſpicion of having bor-

rowed

rowed the conſtruction of theſe watches from any communication of Mr. Mudge's inventions, and at the ſame time ſhewn him not to be deſerving the reproaches, which I underſtand have been thrown upon him by ſome of Mr. Mudge's friends, as if he had prevented him from receiving the reward.

After all, Mr. Mudge, in p. 43, owns himſelf at a loſs to account for my enmity to his ſucceſs. No wonder he cannot account for what does not exiſt. Here however he contradicts what he had ſaid before, in the note p. 4, of my having a private intereſt to induce me to wiſh ill to mechanics, as being candidates for the ſame prize of the longitude with myſelf. This ſhews he does not believe what he there aſſerted, and which indeed it is impoſſible he ſhould believe, becauſe the rewards offered by the act of Parliament, for improving the aſtronomical tables, and for improving time-keepers, are diſtinct from one another; beſides that I have never ſhewn any inclination to become a candidate for any of theſe rewards.

I have now anſwered all Mr. Mudge's objections to my trials of his time-keepers in the courſe of ſixteen years, I flatter myſelf, to the ſatisfaction of the impartial reader; and have given reaſons, which I apprehend will be thought

ſufficiently

ſufficiently cogent to juſtify my calculations of their errors, and have further ſhewn, that even according to his own method of calculation they have erred beyond all the limits of the act. I have pointed out the kindneſs and generoſity of the Board of Longitude towards him, in giving him £. 500 to enable him to make two time-keepers to contend for the prize of the longitude, and their great indulgence in granting him three ſeparate trials of the ſame in the courſe of 11 years, in all which however they have unfortunately failed. I ſhall forbear making any remarks on the ingratitude, indecency, or aſſurance of his behaviour, after ſo many favours received, in endeavouring to traduce and bring into contempt this valuable national committee, under the name of the Aſtronomer Royal, their official agent, and in vilifying a public officer in the groſſeſt manner, and, without any proof whatſoever, accuſing him of the baſeſt actions in the execution of his office, and in his faithful and zealous exertions to aſſiſt the Board of Longitude in carrying their uſeful and important views into execution; but ſhall leave them to the reflection of the readers.

Shall this great and enlightened nation ſuffer an intereſted watch-maker, or the aſtronomer of a foreign prince, or any foreigner, to dictate to them the mode of trying time-keepers? when they have a Board of Longitude expreſsly appointed

pointed by Act of Parliament to conſider theſe matters, compoſed of the principal officers of the naval adminiſtration of government, the Speaker of the Houſe of Commons, the chief Admirals of the Navy, the Preſident of the Royal Society, the Aſtronomer Royal, and the learned Profeſſors of Mathematics and Aſtronomy at both univerſities; an inſtitution which has not its like in any other nation; which cauſes the nautical almanac and aſtronomical ephemeris to be accurately computed and publiſhed in advance, agreeable to act of Parliament, confeſſedly the moſt exact performance of the kind extant, at once uſeful to aſtronomers at land ſtriving to extend their ſcience by their obſervations and calculations united, and to ſailors labouring at ſea to carry the commerce or arms of their country to the moſt diſtant parts of the globe; which by its well-judged encouragements and rewards has brought forward and publiſhed the dividing circular arches of moderate radii and ſtraight lines to the amazing exactneſs of $\frac{1}{3000}$ of an inch by Mr. Ramſden; and a conſiderable improvement of the lunar tables, by Mr. Charles Maſon, made under my direction, and by rules furniſhed by myſelf, from which the nautical almanac is now conſtructed; which has liberally aſſiſted Mr. Arnold to bring his time-keepers to a great degree of perfection, which are now made and ſold by him and many other artiſts in conſiderable

numbers

numbers every year; and which finally has enriched geography with the determination of the latitudes and longitudes of innumerable places, by obſervations made in the courſe of ſeveral voyages round the world by capable perſons employed by them for that purpoſe. But the uſefulneſs of the Board of Longitude is too well known to the public, and acknowledged by all but a diſappointed artiſt, to require my pointing out inſtances in which they have materially ſerved the public, and done honour to the nation. Doubtleſs they deſerve commendation in another reſpect, for having been careful concerning the diſtribution of the public money. They might indeed have been properly cenſured, if they had given it away to a perſon not legally entitled to it by the act of parliament, or by a partial preference of the leſs deſerving perſon to the more deſerving ones.

APPENDIX,

APPENDIX, N° I.

COPY of Minutes of the Board of Longitude, relating to the Trials of Mr. Harriſon's Watch.

17th Auguſt 1762.

MR. Harriſon was called in, and acquainted with theſe reſolutions; and being aſked if he was willing that his watch ſhould be ſent to the Royal Obſervatory at Greenwich, in order that ſome obſervations may be made at that place for the trial of it by Mr. Bliſs, previous to its being ſent to the Weſt Indies, he conſented thereto ſo ſoon as it ſhall have undergone ſome alterations, which he thinks will bring it to greater perfection, the doing of which would probably take up four or five months. Mr. Bliſs was deſired, ſo ſoon as the ſaid watch ſhould be ſent to him, to take the trouble of making ſuch obſervations at Greenwich, as he ſhould judge neceſſary for the trial thereof, previous to its being ſent to the Weſt Indies.

4th Auguſt 1763.—Mr. Harriſon jun. (his father not being preſent) was called in, and aſked if he had any objections to his time-keeper being ſent to the Royal Obſervatory for the previous obſervations to be made by Mr. Bliſs, agreeable to

to the minutes of the 17th Auguſt 1762; he ſaid, that he did object to it, as he does not chuſe to part with it out of his own hands till he ſhall have reaped ſome advantage from it.

Mr. Harriſon then deſired that Captain Campbell, a gentleman well ſkilled in mathematics, may be called in, and aſked his opinion thereon; which being conſented to, Captain Campbell was introduced; and being aſked if he thought the previous obſervations before mentioned neceſſary? ſaid, that he was of opinion if Mr. Harriſon will ſend the rate of the going of his time-keeper before he ſails from Portſmouth, and abide thereby, it might be ſufficient; but that he did not ſee any objection to the previous obſervations being made aſhore as propoſed. It was then propoſed to Mr. Harriſon, that he ſhould ſend the rate of his time-keeper's going (immediately before he ſails on his intended voyage) ſealed up to the Secretary of the Admiralty, and abide thereby upon its trial; to which he conſented.

26th April, 1766.—The Board came to the following reſolutions, relative to Mr. Harriſon's watch, grounded upon a plan laid before them by the Earl of Morton, viz.

That the Lords of the Admiralty be deſired to deliver it into the cuſtody of the Aſtronomer Royal.

That

That it be kept in the Royal Obſervatory at Greenwich, in a box having two different locks, fixed to the floor or wainſcot, with a plate of glaſs in the lid or ſide of the ſaid box; and that it be compared as often as convenient with the regulator, and the variations ſet down.

That the form which Mr. Harriſon obſerved in winding it up, be exactly followed.

That the Lords of the Admiralty be deſired to give directions, that one of the captains or lieutenants of Greenwich Hoſpital may attend every day at the Obſervatory, at a ſtated hour, to witneſs the winding up of the ſaid watch, and the compariſon of it with the regulator.

That a key of one of the locks be kept at the ſaid Hoſpital, for the uſe of thoſe officers, and the other to remain at the Obſervatory, for the uſe of the Royal Aſtronomer, or his aſſiſtant.

That the watch be tried in various poſitions till the beginning of July next; and from thence to the end of February following in a horizontal poſition, with the face upwards.

That the variation of the watch be noted down, and a regiſter of the barometer and thermometer, at the times of comparing the ſame with the regulator, be regularly kept, and atteſted by the Royal Aſtronomer or his aſſiſtant; and ſuch of the officers above mentioned as ſhall,

 from

from time to time, attend to ſee the ſaid watch wound up, and compared as aforeſaid.

11th April 1767.—In reſpect to the mode offered by Mr. Harriſon for the trial of the two time-keepers above-mentioned when compleated, the Board was of opinion the ſame would not be ſufficient, and therefore reſolved upon the following mode in lieu thereof, viz.

That the ſaid two time-keepers, when completed by Mr. Harriſon, be tried together at the Royal Obſervatory for the ſpace of ten ſucceſſive months, including the extremes of natural heat and cold, and two months in the Downs; under the ſame precautions of ſecuring the ſaid time-keepers (under locks with different keys, entruſted to different perſons) as were made uſe of in the voyage to Jamaica and Barbadoes; that in caſe the natural heat of the ſeaſon in the place where the ſaid time-keepers ſhall be kept at the Royal Obſervatory does not ariſe to the degree of 86, according to Fahrenheit's thermometer, an artificial heat be applied ſufficient to raiſe the thermometer to that degree.

H. PARKER,
Secretary to the Commiſſioners
of the Longitude.

APPENDIX,

APPENDIX, N° II.

COPY of Minutes of the Board of Longitude, relating to Mr. Mudge's Time-keepers.

25 June, 1774.

A Letter of the 2d inſtant, from Mr. Thomas Mudge to the Earl of Sandwich, was read, repreſenting that having made a watch or time-keeper, which he flatters himſelf is not void of merit, and may be of ſome uſe to aſcertain the longitude at ſea, he could wiſh to have it tried under the orders of the Board of Longitude. And the Board underſtanding that Mr. Dutton, a watch-maker, was attending with the ſaid watch, he was called in, and exhibited the ſame; and at the ſame time informed the Board, that Mr. Mudge ſubmitted the trial of it intirely to the Board, either by Mr. Maſkelyne, in the ſame way that other time-keepers have been tried at the Royal Obſervatory at Greenwich, or in any other manner that they ſhould judge proper—Reſolved, That the ſaid watch be ſent to Mr. Maſkelyne, when he returns to Greenwich, and that he be deſired to make trial of it accordingly, and after a proper time to report the reſult of his obſervations thereupon to the Board. And

Mr.

Mr. Dutton having been made acquainted with this reſolution, and deſired to communicate it to Mr. Mudge, that the watch may be ſent to the Royal Obſervatory for trial accordingly, he withdrew.

4th March, 1775.—The Aſtronomer Royal then delivered to the Board an account of the going of Mr. Mudge's watch, from the 14th December laſt, to the 1ſt inſtant, together with a mean ſtate of a thermometer placed near it.

27th May, 1775.—The ſpeaker informed the Board, that Mr. Mudge had ſeveral objections to make to that part of the act of the 14th of his preſent Majeſty which relates to time-keepers. And the Board underſtanding that the ſaid Mr. Mudge was attending, he was ſent for in, and was told, that if he would reduce thoſe objections into writing, and ſend them to the ſecretary, they ſhould be taken into conſideration, in order that, if they had weight in them, and could not be anſwered, application might be made to parliament for an act to explain and amend the act before mentioned. He then made objections to the place in which his time-keeper had been tried at the Royal Obſervatory. And being aſked, if he would be ſatisfied to have the ſame tried in the tranſit room, where the other time-keepers have been tried? he declared he would, and then

then withdrew; and the Aſtronomer Royal was deſired to try it in that room accordingly.

2d November, 1776.—Mr. Dutton attended with Mr. Mudge's watch, and Mr. Maſkelyne was deſired, and undertook, to try it again at the Royal Obſervatory, in the ſame room wherein Mr. Harriſon's watch was tried.

1ſt March, 1777.—The Aſtronomer Royal reported to the Board that the watch made by Mr. Mudge, which has been at the Royal Obſervatory for trial in conſequence of the reſolutions of laſt board, had gained in 109 days only 1′ 19″, and that it is greatly ſuperior in point of accuracy to any time-keeper which hath come under his inſpection. And the Board, underſtanding that Mr. Mudge hath an intention of making two other watches of the ſame kind, in order to endeavour to obtain a greater degree of perfection, provided he can have ſome aſſiſtance from them to enable him to do ſo—Reſolved, in conſideration of the very favourable report given by the Aſtronomer Royal as above mentioned, That a letter be written to the Navy Board, deſiring them to cauſe £. 500 to be advanced to the ſaid Mr. Mudge, to enable him to complete two more watches accordingly.

7th July

7th June, 1777.—Reſolved, That a letter be written to the Navy Board, for paying Mr. Mudge the £. 500 ordered by laſt Board.

10th July 1779.—The Aſtronomer Royal laid before the Board, an account of the going of Mr. Mudge's two watches.

27th November 1779.—The Aſtronomer Royal preſented to the Board, an account of the going of Mr. Mudge's two watches, from the 10th July laſt to the preſent time.

4th March, 1780.—The Aſtronomer Royal laid before the Board the rates and going of Mr. Mudge's two time-keepers, Blue and Green, from the 21ſt April, 1779, to 29th February, 1780.

15th July, 1780.—The Aſtronomer Royal having acquainted the Board, that Mr. Mudge had deſired to have his two watches from the Royal Obſervatory, in order to make ſome obſervations upon them; he was told the Board had no objection thereto.

3d March, 1781.—The Aſtronomer Royal preſented to the Board, an account of the going of Mr. Mudge's two watches, from the 1ſt March to the 14th and 15th July, 1780.

19th July,

19th July, 1783.—The Board having underſtood that Mr. Dutton was attending, he was called in, and produced two watches from Mr. Mudge, which he deſired might be tried at the Royal Obſervatory.—Reſolved, That the Aſtronomer Royal be deſired to receive the ſaid watches under his care, try their rate of going, and report the reſult to this Board.

6th March, 1784.—The Aſtronomer Royal laid before the Board the daily rate of going of Mr. Mudge's time-keepers, diſtinguiſhed by the titles of Green and Blue, at the Royal Obſervatory at Greenwich, between the 21ſt of July, 1783, and 1ſt March, 1784.

24th Auguſt, 1784.—The Aſtronomer Royal delivered to the Board an account of the rates of going of Mr. Mudge's two watches, from the 5th March laſt to the 21ſt Auguſt; alſo calculations of the total variations of theſe two time-keepers, from the 21ſt of July, 1783, to the 21ſt Auguſt, 1784, by which it appears that the watch diſtinguiſhed by the appellation of Green, varied

1′. 25″, in the firſt ſix months, beginning 20th Auguſt, 1783,

7. 6, in the ſecond ſix months, beginning 20th February, 1784;

and that the watch diſtinguiſhed by the appellation of Blue, varied

5′. 43″, in the firſt ſix months, beginning 20th Auguſt, 1783,

11. 4, in the ſecond ſix months, beginning 20th February, 1784;

and that their rates of going are not therefore exact enough to merit the great reward given by act of parliament.

29th November, 1788.—The Aſtronomer Royal then informed the Board, that Mr. Mudge had made ſome corrections and improvements in his watches, and wiſhed another trial might be made of them at the Royal Obſervatory at Greenwich.—The Aſtronomer Royal was thereupon deſired to receive the ſaid watches into his charge, try their rate of going, and report the reſult to the Board.

15th Auguſt, 1789.—The Aſtronomer Royal laid before the Board the rate of going of Mr. Mudge's two watches, from 24th June laſt, to the 14th of this month.

6th March, 1790. The Aſtronomer Royal made a further report of the rate of going of

Mr. Mudge's two watches, to the end of laſt month.

5th June, 1790.—The Aſtronomer Royal made a further report upon the rate of going of Mr. Mudge's two watches; and at the ſame time informed the Board, that the year of trial directed by act of parliament to be made of them at the Royal Obſervatory at Greenwich, was near expiring. The Board were thereupon pleaſed to direct, that upon the expiration of the year's trial, the ſecretary ſhould acquaint Mr. Mudge, that the report from the Aſtronomer Royal, upon the rate of going of his watches, would be taken into conſideration at the next meeting of the Board, on the firſt Saturday in December: and if in the mean while he wiſhes to have them returned to him to be cleaned, previous to their undergoing ſuch farther trial as the Board may direct, he is to make application for them to the Aſtronomer Royal.

4th December, 1790.—A letter was read from Mr. Thomas Mudge, of Lincoln's Inn, declining, in his father's name, the offer made him by order of the Board, of having his two time-keepers returned to him to be cleaned, previous to their undergoing farther trial. The Aſtronomer Royal then delivered an account of the rate of going of

Mr. Mudge's two time-keepers marked Green and Blue, which had been twelve months under trial at the Royal Obſervatory at Greenwich; from which account it appears, that the errors of the ſaid time-keepers, in the ſeveral periods of ſix months, beginning the 24th July, 1789, and ending 29th of June, 1790, were as follows; viz.

Errors

Errors in Time-keeper marked Green.

Beginning with	1789.	and ending with	1790.	are
July - - - 24		Jan. - - - 29		+ 2′. 41″
Aug. - - - 24		Feb. - - - 28		+ 4. 6
Sept. - - - 24		Mar. - - - 29		+ 5. 28
Oct. - - - 24		Apr. - - - 29		+ 7. 4
Nov. - - - 24		May - - - 29		+ 6. 5
Dec. - - - 24		June - - - 29		+ 3. 36

Errors in Time-keeper marked Blue.

Beginning with	1789.	and ending with	1790.	are
July - - - 24		Jan. - - - 29		+ 3′. 5″
Aug. - - - 24		Feb. - - - 28		+ 4. 10
Sept. - - - 24		Mar. - - - 29		+ 5. 11
Oct. - - - 24		Apr. - - - 29		+ 6. 35
Nov. - - - 24		May - - - 29		+ 6. 31
Dec. - - - 24		June - - - 29		+ 6. 0

It was thereupon reſolved, That as the ſaid time-keepers had not gone upon the twelve-month's trial with the exactneſs required by the act of the 14th of the preſent king, the Board were not authorized to order further trial of them.

3d March, 1792.—The Aſtronomer Royal repreſented to the Board, that he had been reflected upon in a pamphlet publiſhed by Mr. Thomas Mudge, as being particularly intereſted in the improvement of the various aſtronomical tables in uſe for the diſcovery of the longitude, and of receiving conſiderable ſums of money from time to time from the Board, for the conſtruction of them; and requeſted the Board would by ſome minute or reſolution vindicate him from theſe aſperſions; and that they would permit him to have atteſted copies from ſuch of the minutes of the Board as he might think neceſſary for his juſtification.

And the Board having taken the ſame into their conſideration, unanimouſly reſolved, That the Board have never ordered any money to be paid or impreſted to the Aſtronomer Royal, for the conſtruction or improvement of the tables above mentioned, or any other work, but what hath been, and is expected to be regularly and punctually accounted for, without any benefit or advantage

advantage whatever to himſelf, ſo far as the members of the Board know, or have any reaſon to believe.

Reſolved, That the Secretary be directed to furniſh the Aſtronomer Royal with atteſted copies of ſuch of the Board's minutes as he may think neceſſary for his juſtification; and that he may have leave to publiſh the ſame, if he thinks proper.

H. PARKER,
Secretary to the Commiſſioners
of the Longitude.

APPENDIX, N° III.

COPY of a Letter from Dr. Zach to Sir Joſeph Banks, concerning ſome ſuppoſed Errors of the Nautical Almanac, &c.

SIR, *Dover Street, 28th April,* 1786.

COUNT BRUHL's very exact obſervations and rate-keeping of three time-pieces, a pendulum clock of Mr. Mudge, a time-keeper of the ſame artiſt, and a pocket chronometer of Mr. Emery, have firſt given riſe to ſuſpect the ſun's right aſcenſion, and the equation of time, in the nautical almanac, ſometimes erroneous, and which the moſt remarkable rate of going of thoſe three machines could only have pointed out; for as it is beyond all probability that three moſt excellent machines ſhould altogether, and all at once, be affected by the ſame jerks, ſo it is more likely and more rational to put them on account of the ſolar tables, or perhaps on account of the errors which may be committed in computing the elements of time in the nautical almanac, and which are uſed to reduce the obſervations; his Excellency having therefore often complained

plained to me upon like occaſions, I ſeveral times undertook to calculate theſe elements very rigorouſly myſelf, and upon examining this matter with more attention, I very ſoon found out that the errors and omiſſions in the nautical almanac will ſometimes lead into errors of very near one ſecond in time, which has therefore induced us not to uſe any more a datum of the nautical almanac for that purpoſe, but to calculate our own equation of time and right aſcenſion rigorouſly, and by the exacteſt theory, in order to find our time, and to keep a fair and more exact regiſter of the time-pieces, which being brought to ſuch a pitch of perfection are indeed in the ſtate to be attended even as near as 0,2 of a ſecond; his Excellency, as well as myſelf, always pretending to that preciſion in all our obſervations. This fact I mentioned to you, ſir; you deſire now ſome proofs of it; here I have the honor to ſend you ſome— Let us for inſtance, look for the ☉'s A.R. and equation of time in the year 1783, June the 22d; the nautical almanac gives you for the former 6ʰ. 3′ 36″,0 for the latter + 1′ 25″,8. My computation ſtands thus:

	Long. med.	Apog.	☾	☿	♀	♂	″	″
	° ′ ′ ″	° ′ ′ ″						
1783 - -	9. 10. 1. 28,9	3. 9. 13. 52	- 899	- 984	- 492	- 994	☾ —8,0	♃ +1,7
22 June -	5. 20. 31. 1,2	31	858	434	296	25	☿ —2,1	♂ +2,2
1′. 25″,8 - - - - - -	3,6							
		3. 9. 14. 23	757	418	788	19	—10,1	+3,9
							+3,9	
	3. 0. 32. 33,7	Anom. 11. 21. 18. 11					—6,2	
Equat. Cent.	+17. 6,8 - - - -				in time -	+1″ 8‴,45		
						17,88		
	3. 0. 49. 40,5							
IV Eq.	—6,2					1. 26,33		
					IV Eq. -	6″,2 - —,41		
Long. vera ☉	3. 0. 49. 34,3 in time 6ʰ. 3′. 18″,28					1. 25,92 Equat. time		
Reduct. - - -	+4. 28,1							
A.R. vera -	3. 0. 54. 2,4 in time 6. 3. 36,16							
	diff. - -	+17,88						

Observing

Therefore by my calculation the ☉'s Right Asc. - -	6. 3. 36,2	- Equat. of Time -	1. 25,9
by Nautical Almanac - - - - - - - - - -	6. 3. 36,0	-	1. 25,8
	Differ. . 0,2		,01

Obſerving therefore noon by the pendulum clock in ſiderial time, and reducing it by the AR and equation of time to mean time, the error committed will be - 0″,3
taking in the effect of nutation upon the equation of time omitted in the nautical almanac, it can amount when at its maximum - 0,3
The difference of attraction by ♀ as ſettled by Mr. Lexell, according to the theory of Mr. Euler, and which enquiry Dr. Hornſby has occaſioned when Mr. Lexell was in England, will amount to, when at its maximum - - 0,3

When theſe errors conſpire in one way, they will produce one of 0,9 in time.

Errors of 0″,2 in time will alſo be found 1783, June 21; 1786, April 17th; which ſhews ſufficiently that attention ought to be paid to ſuch differences, by no means trifling, in keeping exact and true regiſters of time-pieces, eſpecially if they are kept after the method in uſe at the Royal Obſervatory, a method diſapproved by every body who is acquainted with that ſubject, and which, inſtead of encouraging and ſupporting the genius of artiſts, tends rather to abate

it; for as long as this method will not be altered, there are artists, especially Mr. Mudge himself, who never will submit his time-keepers to another trial at the Royal Observatory; Sir Joseph will therefore do a very important service to nautical, geographical, and astronomical science in general, and in particular to his own nation, which already has so generously promoted this matter, by bringing the Astronomer Royal to lay before the Board of Longitude the bare registers of the daily rates of going of the time-pieces committed to his examination; and by saving him the trouble of constructing such tables, which will shew the best pendulum-clock art has constructed hitherto, but a very indifferent machine.

I am, with the greatest esteem and regard,

Sir, your most humble, obedient servant,

FR. de ZACH.

Sir Joseph Banks, Bart.
President of the Royal Society.

APPEN-

APPENDIX, N° IV.

ABSTRACT of the going of Mr. MUDGE's First Time-keeper, in 1776, 1777, and 1778.

The Daily Rate made use of in the following Calculations is taken + 0″, 119 from the mean of the Daily Rates of the First Month, from Nov. 11th to Dec. 11th 1776.

Day of the Month.	Sum of daily rates from Nov. 11, 1776.	Computed Variation from Nov. 11, 1776.	Error of Watch from Nov. 11, 1776.	Day of the Month.	Sum of daily rates from Nov. 11, 1776.	Computed Variation from Nov. 11, 1776.	Error of Watch from Nov. 11, 1776.	Error of Watch in six Months, = col. 8.—col. 4.
1776.				1777.				
Dec. 11	+ 0. 3,57	+ 0. 3,57	0. 0, 0	June 11.	+ 7. 21,55	+ 0. 25,23	+ 6. 56, 4	+ 6. 56
1777.				July 11.	+ 9. 5,10	+ 0. 28,80	+ 8. 36, 3	+ 8. 28
Jan. 11.	+ 0. 15,84	+ 0. 7,26	+ 0. 8, 5	Aug. 11.	+ 10. 56,17	+ 0. 32,49	+ 10. 23, 7	+ 9. 43
Feb. 11.	+ 0. 51,97	+ 0. 10,95	+ 0. 41, 0					
Mar. 11.	+ 1. 51,96	+ 0. 14,28	+ 1. 37, 7	Sept. 11.	+ 12. 42,30	+ 0. 36,18	+ 12. 6, 1	+ 10. 28
April 11.	+ 3. 44,26	+ 0. 17,97	+ 3. 26, 3	Oct. 11.	+ 14. 38,92	+ 0. 39,75	+ 13. 59. 1	+ 10. 33
May 11.	+ 5. 31,75	+ 0. 21,54	+ 5. 10, 3	Nov. 11.	+ 16. 49,49	+ 0. 43,44	+ 16. 6, 1	+ 10. 56
June 11.	+ 7. 21,55	+ 0. 25,23	+ 6. 56, 4	Dec. 11.	+ 19. 25,32	+ 0. 47,01	+ 18. 38, 3	+ 11. 42
				1778.				
July 11.	+ 9. 5,10	+ 0. 28,80	+ 8. 36, 3	Jan. 11.	+ 22. 41,49	+ 0. 50,69	+ 21, 50, 8	+ 13. 14
Aug. 11.	+ 10. 56,17	+ 0. 32,49	+ 10. 23, 7	Feb. 11.	+ 25. 56,68	+ 0. 54,38	+ 25. 2, 3	+ 14. 39
				Feb. 16.	+ 26. 35,14	+ 0. 54,98	+ 25. 40. 1	- - - -

APPENDIX, N° V.

Abstract of the going of Mr. Mudge's Watch Green, in 1779 and 1780.

The Daily Rate made use of in the following Calculations, is taken — 2,″ 10 from the Mean of the Daily Rates of 41 Days, from April 20 to May 31, 1779.

Day of the Month.	Sum of daily rates from May 31, 1779.	Sum of what the Watch ought to have lost.	Difference, or what the Watch has gained.	Day of the Month.	Sum of daily rates from May 31, 1779.	Sum of what the Watch ought to have lost.	Difference, or what the Watch has gained.	Error of Watch in 183 days = 6 Months.
1779.	′ ″	′ ″	′ ″	1779.	′ ″	′ ″	′ ″	′ ″
May 31.	0. 0, 0	0. 0, 0	0. 0, 0	Nov. 30.	+ 1. 12,26	— 6. 24,30	+ 7. 36,56	+ 7. 37
June 30.	— 0. 18,22	— 1. 3, 0	+ 0. 44,78	Dec. 30.	+ 1. 45,60	— 7. 27,30	+ 9. 12,90	+ 8. 28
				1780.				
July 31.	— 0. 23,36	— 2. 8,10	+ 1. 44,74	Jan. 30.	+ 0. 39,27	— 8. 32,40	+ 9. 11,67	+ 7. 27
Aug. 31.	— 0. 21,71	— 3. 13,20	+ 2. 51,49	Mar. 4.	+ 0. 34,25	— 9. 37,50	+ 10. 11,75	+ 7. 20
Sept. 30.	— 0. 9,62	— 4. 16,20	+ 4. 16,58	April 3.	+ 2. 39,25	— 10. 40,50	+ 13. 19,75	+ 9. 3
Oct. 31.	+ 0. 45,86	— 5. 21,30	+ 6. 7,16	May 4.	+ 4. 43,34	— 11. 45,60	+ 16. 28,94	+ 10. 22
Nov. 30.	+ 1. 12,26	— 6. 24,30	+ 7. 36,56	June 3.	+ 8. 12,14	— 12. 48,60	+ 21. 0,74	+ 13. 24
Dec. 30.	+ 1. 45,60	— 7. 27,30	+ 9. 12,90	July 3.	+ 11. 45,98	— 13. 51,60	+ 25. 37,58	+ 16. 25
				July 17.	+ 13. 30,75	— 14. 21,00	+ 27. 51,75	

APPENDIX, N° VI.

Abstract of the going of Mr. Mudge's Watch Blue, in 1779 and 1780.

The Daily Rate made use of in the following Calculations is taken — 1″, 74; from the Mean of the Daily Rates of 41 Days, from April 20 to May 31, 1779.

Day of the Month.	Sum of daily rates from May 31, 1779.	Sum of what the Watch ought to have lost.	Difference, or what the Watch has lost or gained.	Day of the Month.	Sum of daily rates from May 31, 1779.	Sum of what the Watch ought to have lost.	Difference, or what the Watch has gained.	Error of Watch in 183 Days = 6 Months.
1779.	′ ″	′ ″	′ ″	1779.	′ ″	′ ″	′ ″	′ ″
May 31.	0. 0, 0	0. 0, 0	0. 0, 0	Nov. 30.	+ 0. 34,53	— 5. 18,42	+ 5. 52,95	+ 5. 53
June 30.	— 0. 54,24	— 0. 52,20	— 0. 2,04	Dec. 30.	+ 3. 54,34	— 6. 10,62	+ 10. 4,96	+ 10. 7
				1780.				
July 31.	— 1. 30,89	— 1. 46,14	+ 0. 15,25	Jan. 30.	+ 8. 38,80	— 7. 4,56	+ 15. 43,36	+ 15. 28
Aug 31.	— 2. 12,07	— 2. 40,08	+ 0. 28,01	Mar. 4.	+ 13. 47,36	— 7. 58,60	+ 21. 45,96	+ 21. 18
Sept. 30.	— 2. 22,51	— 3. 32,28	+ 1. 9,77	Ap. 3.	+ 18. 33,74	— 8. 50,80	+ 27. 24,54	+ 26. 15
Oct. 31.	— 1. 52,23	— 4. 26,22	+ 2. 33,99	May 4.	+ 23. 51,39	— 9. 43,00	+ 33. 34,39	+ 31. 0
Nov. 30.	+ 0. 34,53	— 5. 18,42	+ 5. 52,95	June 3.	+ 28. 50,45	— 10. 35,20	+ 39. 25,65	+ 33. 33
Dec. 30.	+ 3. 54,34	— 6. 10,62	+ 10. 4,96	July 3.	+ 35. 3,35	— 11. 27,40	+ 46. 30,75	+ 36. 26
				July 17.	+ 38. 31,18	— 11. 51,76	+ 50. 22,94	

APPENDIX

APPENDIX, N° VII.

ABSTRACT of the going of Mr. MUDGE's Watch Green, in 1783 and 1784.

The Daily Rate made use of in the following Calculations is taken—0″, 09; from the Mean of the Daily Rates of the First Month, from July 21 to August 20, 1783.

Day of the Month.	Sum of daily rates from Aug. 20, 1783.	Sum of what the Watch ought to have lost.	Difference or what the Watch has gained.	Day of the Month.	Sum of daily rates from Aug. 20, 1783.	Sum of what the Watch ought to have lost.	Difference or what the Watch has gained.	Error of the Watch in 183 Days = 6 Months.
1783.	′ ″	′ ″	′ ″	1784.	′ ″	′ ″	′ ″	′ ″
Aug. 20.	0. 0, 0	0. 0, 0	0. 0, 0	Feb. 20.	+ 1. 8,14	— 0. 16,56	+ 1. 24,70	+ 1. 25
Sept. 20.	+ 0. 11,58	— 0. 2,79	+ 0. 14,37	Mar. 20.	+ 1. 55,35	— 0. 19,17	+ 2. 14,52	+ 2. 0
Oct. 20.	+ 0. 41,72	— 0. 5,50	+ 0. 47,22	April 20.	+ 2. 25,89	— 0. 21,96	+ 2. 47,85	+ 2. 1
Nov. 20.	+ 1. 45,71	— 0. 8,28	+ 1. 53,99	May 21.	+ 3. 51,14	— 0. 24,66	+ 4. 15,80	+ 2. 22
Dec. 20.	+ 2. 52,08	— 0. 10,98	+ 3. 3,06	June 21.	+ 5. 9,71	— 0. 27,45	+ 5. 37,16	+ 2. 34
1784.								
Jan. 20.	+ 2. 22, 0	— 0. 13,77	+ 2. 35,77	July 21.	+ 6. 30,15	— 0. 30,15	+ 7. 0,30	+ 4. 25
Feb. 20.	+ 1. 8,14	— 0. 16,56	+ 1. 24,70	Aug. 21.	+ 8. 1,42	— 0. 32,94	+ 8. 34,36	+ 7. 10
Mar. 20.	+ 1. 55,35	— 0. 19,17	+ 2. 14,52	Sep. 12.	+ 9. 8,17	— 0. 34,92	+ 9. 43,09	

APPENDIX, N° VIII.

Abstract of the going of Mr. Mudge's Watch Blue, in 1783 and 1784.

The Daily Rate made use of in the following Calculations is taken + 0″, 43 from a Mean of the Daily Rates of the first Month, from July 21 to Aug. 20, 1783.

Day of the Month.	Sum of Daily Rates from Aug. 20, 1783.	Sum of what the Watch ought to have gained.	Difference, or what the Watch has gained.	Day of the Month.	Sum of Daily Rates from Aug. 20, 1783.	Sum of what the Watch ought to have gained.	Difference, or what the Watch has gained.	Error of the Watch in 183 Days = 6 Months.
1783.	′ ″	′ ″	′ ″	1784.	″	′ ″	′ ″	′ ″
Aug. 20.	0. 0 ,0	0. 0, 0	0. 0, 0	Feb. 20.	+ 7. 1,88	+ 1. 19,12	+ 5. 42,76	+ 5. 43
Sept. 20.	+ 0. 53,06	+ 0. 13,33	+ 0. 39,73	Mar. 20.	+ 8. 8,69	+ 1. 31,59	+ 6. 37,10	+ 5. 57
Oct. 20.	+ 2. 18,40	+ 0. 26,23	+ 1. 52,17	April 20.	+ 9. 23,76	+ 1. 44,92	+ 7. 38,84	+ 5. 47
Nov. 20.	+ 3. 46,01	+ 0. 39,56	+ 3. 6,45	May 21.	+ 11. 30,97	+ 1. 57,82	+ 9. 33,15	+ 6. 27
Dec. 20.	+ 4. 44,79	+ 0. 52,46	+ 3. 52,33	June 21.	+ 13. 46,26	+ 2. 11,15	+ 11. 35,11	+ 7. 43
1784.								
Jan. 20.	+ 5. 52,86	+ 1. 5,79	+ 4. 47,07	July 21.	+ 16. 23,59	+ 2. 24,05	+ 13. 59,54	+ 9. 12
Feb. 20.	+ 7. 1,88	+ 1. 19,12	+ 5. 42,76	Aug. 21.	+ 19. 31,88	+ 2. 37,38	+ 16. 54,50	+ 11. 12
Mar. 20.	+ 8. 8,69	+ 1. 31,59	+ 6. 37,10	Sept. 12.	+ 21. 53,53	+ 2. 46,84	+ 19. 6,69	

APPENDIX, N° IX.

ABSTRACT of the going of Mr. MUDGE's Watch Green, in 1789 and 1790.

The Daily Rate made use of in the following Calculations is taken +0″,021 from a Mean of the Daily Rates of the First Month, from June 24th to July 24th 1789.

1789.	Sum of daily rates from June 24, 1789.	Computed Variation from June 24, 1789.	Error of Watch from June 24, 1789.	1790.	Sum of Daily Rates from June 24, 1789.	Computed Variation from June 24, 1789.	Error of Watch from June 24, 1789.	Errors in several Periods of Six Months = col. 8.—col. 4
	′ ″	′ ″	′ ″		′ ″	′ ″	′ ″	′ ″
July 24.	+ 0. 0,63	+ 0. 0,63	0. 0, 0	Jan. 29.	+ 2. 45,74	+ 0. 4,49	+ 2. 41, 3	+ 2. 41
Aug. 24.	— 0. 9,87	+ 0. 1,28	— 0. 11, 2	Feb. 28.	+ 4. 0,27	+ 0. 5,12	+ 3. 55, 2	+ 4. 6
Sep. 24.	+ 0. 2,51	+ 0. 1,93	+ 0. 0, 6	Mar. 29.	+ 5. 34,48	+ 0. 5,73	+ 5. 28, 8	+ 5. 28
Oct. 24.	— 0. 20,49	+ 0. 2,56	— 0. 23, 1	April 29.	+ 6. 47,80	+ 0. 6,38	+ 6. 41, 4	+ 7. 4
Nov. 24.	+ 0. 23,28	+ 0. 3,21	+ 0. 20, 1	May 29.	+ 6. 32,34	+ 0. 7,01	+ 6. 25, 3	+ 6. 5
Dec. 24.	+ 1. 41,21	+ 0. 3,84	+ 1. 37, 4	June 29.	+ 5. 21, 0	+ 0. 7,66	+ 5. 13, 3	+ 3. 36
				May 6.	+ 6. 54,49	+ 0. 6,53	+ 6. 48, 0	

APPENDIX, N° X.

ABSTRACT of the going of Mr. MUDGE's Watch Blue, in 1789 and 1790.

The Daily Rate made use of in the following Calculations is taken — 2″,0606 from a Mean of the Daily Rates of the First Month, from June 24 to July 24, 1789.

1789.	Sum of daily rates from June 24, 1789.	Computed Variation from June 24, 1789.	Error of Watch from June 24, 1789.	1790.	Sum of daily rates from June 24, 1789.	Computed Variation from June 24, 1789.	Error of Watch from June 24, 1789.	Errors in several Periods of Six Months = col. 8. — col. 4.
	′ ″	′ ″	′ ″		′ ″	′ ″	′ ″	′ ″
July 24.	— 1. 1,82	— 1. 1,82	0. 0, 0	Jan. 29.	— 4. 15,77	— 7. 20,97	+ 3. 5, 2	+ 3. 5
Aug. 24.	— 2. 12,72	— 2. 5,70	— 0. 7, 0	Feb. 28.	— 4. 19,54	— 8. 22,79	+ 4. 3, 3	+ 4. 10
Sep. 24.	— 3. 21,06	— 3. 9,57	— 0. 11, 5	Mar. 29.	— 4. 23,12	— 9. 22,54	+ 4. 59, 4	+ 5. 11
Oct. 24.	— 4. 8,64	— 4. 11,39	+ 0. 2, 8	April 29.	— 3. 48,44	— 10. 26,42	+ 6. 38, 0	+ 6. 35
Nov. 24.	— 4. 18,72	— 5. 15,27	+ 0. 56, 6	May 29.	— 4. 0,47	— 11. 28,24	+ 7. 27, 8	+ 6. 31
Dec. 24.	— 4. 10,04	— 6. 17,09	+ 2. 7, 0	June 29.	— 4. 24,60	— 12. 32,12	+ 8. 7, 5	+ 6. 0

APPENDIX, N° XI.

ABSTRACT of the going of Mr. MUDGE's Time-keeper called Green, At Mr. Dutton's House, in several Periods of six Months; the Daily Rate being taken from the going in the first Month = + 3″,8443, the Effect of which is set down in the fifth Column of the following Table:

Total Variation from Dec. 14, 1790.	Total Variation from Dec. 14, 1790.	Interval.	Variation of Watch in Six Months = Col. 2. — Col. 1.	Computed Variation in Six Months = 182 Days.	Error of Watch in 182 Days or Six Months = Col. 4 — Col. 5.
1791.		Days.			
Jan. 13. + 1. 55,33	July 14. + 6. 53,67	182	+ 4. 58,34	+ 11. 39,67	— 6. 41
Feb. 13. + 2. 53,33	Aug. 14. + 8. 0,45	182	+ 5. 7,12	+ 11. 39,67	— 6. 33
Mar. 13. + 3. 41,50	Sep. 11. + 8. 51,71	182	+ 5. 10,21	+ 11. 39,67	— 6. 29
April 13. + 4. 29,84	Oct. 12. + 9. 24,25	182	+ 4. 54,41	+ 11. 39,67	— 6. 45
May 13. + 5. 9,70	Nov. 12. + 9. 31,57	182	+ 4. 21,87	+ 11. 39,67	— 7. 18
June 15. + 6. 3,56	Dec. 15. + 9. 31,38	182	+ 3. 27,82	+ 11. 39,67	— 8. 12

APPENDIX, N° XII.

ABSTRACT of the going of Mr. MUDGE's Time-keeper called Blue, at Mr. Dutton's Houſe, in ſeveral Periods of ſix Months; the Daily Rate being taken from the going in the firſt Month = + 3″, 111, the Effect of which is ſet down in the 5th Column of the following Table.

Total Variation from Dec. 14, 1790.	Total Variation from Dec. 14, 1790.	Interval.	Variation of Watch in 6 Months = Col. 2.—Col. 1	Computed Variation in 6 Months = 182 Days.	Error of Watch in 182 Days or ſix Months = Col. 4 — Col. 5	
1791.		Days.				
Jan. 13. + 1′ 33″,33	July 14. + 8′ 59″,42	182	+ 7′ 26″,09	+ 9′ 36″,22	— 2′ 10″	
Feb. 13. + 2. 57,83	Aug. 14. + 10. 16,95	182	+ 7. 19,12	+ 9. 36,22	— 2. 17	
Mar. 13. + 4. 16,25	Sep. 11. + 11. 16,71	182	+ 7. 0, 46	+ 9. 36,22	— 2. 36	
April 13. + 5. 37,34	Oct. 12. + 11. 54,75	182	+ 6. 17,41	+ 9. 36,22	— 3. 19	
May 13. + 6. 34,45	Nov. 12. + 12. 47,07	182	+ 6. 13,62	+ 9. 36,22	— 3. 23	
June 15. + 7. 50,06	Dec. 15. + 13. 50,88	182	+ 6. 0,88	+ 9. 36,22	— 3. 35	

APPENDIX, N° XIII.

Daily Rates of Mr. Mudge's firſt Time-keeper, during four Months and a Half, from Nov. 11, 1776, to March 24, 1777, taken from ſucceſſive Periods of a Week.

		Daily Rates.
		″
1776, Nov.	11, 18.	+ 0,23
	25.	+ 0,63
Dec.	2.	— 0,05
	9.	— 0,13
	16.	— 0,01
	23.	+ 0,25
	30.	+ 0,38
1777, Jan.	6.	+ 0,28
	13.	+ 0,98
	20.	+ 2,32
	27.	+ 1,14
Feb.	3.	+ 0,41
	10.	+ 1,11
	17.	+ 1,08
	24.	+ 1,76
March	3.	+ 2,70
	10.	+ 2,58
	17.	+ 2,28
	24.	+ 3,58

APPENDIX, N° XIV.

Computations of the going of the Watch Green, at the Royal Obſervatory, in ſeveral Periods of ſix Months, by taking the Rates of going from the Month immediately preceding each Period.

Day of the Month.	Variation of Watch, or Sum of Daily Rates from June 24, 1789.	Variation of Watch in each Interval of one Month.	Each interval contains Days.	Six following Months = Days	Computed Variation of Watch in 6 Months from preceding Month's rate.	Period of ſix Months begins at 1789.	Period of ſix Months ends at 1790.	Variation of Watch in the Interval of 6 Months.	Error of Watch in ſix Months.
1789.	′ ″	′ ″						′ ″	′ ″
June 24.	0. 0, 0								
July 24.	+ 0. 0,63	+ 0. 0,63	30	184	+ 0. 3,86	July 24.	Jan. 29.	+ 2.45,11	+ 2.41
Aug. 24.	— 0. 9,87	— 0.10,50	31	183	— 1. 1,98	Aug. 24.	Feb. 28.	+ 4.10,14	+ 5.12
Sept. 24.	+ 0. 2,51	+ 0.12,38	31	181	+ 1.12,28	Sept. 24.	Mar. 29.	+ 5.31,97	+ 4.20
Oct. 24.	— 0.20,49	— 0.23, 0	30	182	+ 2.19,53	Oct. 24.	April 29.	+ 7. 8,29	+ 4.49
Nov. 24.	+ 0.23,28	+ 0.43,77	31	181	+ 4.15,56	Nov. 24.	May 29.	+ 6. 9,06	+ 1.54
Dec. 24.	+ 1.41,21	+ 1.17,93	30	182	+ 7.52,77	Dec. 24.	June 29.	+ 3.39,79	— 4.13
1790.									
Jan. 9.	+ 2.45,74	+ 1. 4,53	31						
Feb. 28.	+ 4. 0,27	+ 1.14,53	30						
Mar. 29.	+ 5.34,48	+ 1.34,21	29						
April 29	+ 6.47,80	+ 1.13,32	31						
May 29.	+ 6.32,34	— 0.15,46	30						
June 29.	+ 5.21, 0	— 1.11,34	31						

APPENDIX.

APPENDIX, N° XV.

Computations of the going of the Watch Blue, at the Royal Obſervatory, in ſeveral Periods of ſix Months, by taking the Rates of going from the Month immediately preceding each Period.

1789.	Variation of Watch, or Sum of Daily Rates from June 24.	Variation of Watch in each Interval of One Month.	Each Interval contains Days.	Six following Months = Days.	Computed Variation of Watch in Six Months from preceding Month's Rate	Period of Six Months begins at 1789.	Period of Six Months ends at 1790.	Variation of Watch in the Interval of Six Months.	Error of Watch in Six Months.
	′ ″								
June 24.	— 0. 0, 0								
July 24.	— 1. 1,82	— 1. 1,82	30	184	— 6. 19,76	July 24.	Jan. 29.	— 3. 13,95	+ 3. 6
Aug. 24.	— 2. 12,72	— 1. 10,90	31	183	— 6. 58,54	Aug. 24.	Feb. 28.	— 2. 6,82	+ 4. 52
Sep. 24.	— 3. 21,06	— 1. 8,34	31	181	— 6. 39,02	Sep. 24.	Mar. 29.	— 1. 2,06	+ 5. 37
Oct. 24.	— 4. 8,64	— 0. 47,58	30	182	— 4. 48,65	Oct. 24.	April 29.	+ 0. 20,20	+ 5. 9
Nov. 24.	— 4. 18,72	— 0. 10,08	31	181	— 0. 58,85	Nov. 24.	May 29.	+ 0. 18,25	+ 1. 17
Dec. 24.	— 4. 10,04	+ 0. 8,68	30	182	+ 0. 52,66	Dec. 24.	June 29.	— 0. 14,56	— 1. 7
1790.		— 0. 5,73	31						
Jan. 29.	— 4. 15,77	— 0. 3,77	30						
Feb. 28.	— 4. 19,54	— 0. 3,68	29						
Mar. 29.	— 4. 23,12	+ 0. 34,68	31						
April 29.	— 3. 48,44	— 0. 12,03	30						
May 29.	— 4. 0,47	— 0. 24,13	31						
June 29.	— 4. 24,60								

APPENDIX, N° XVI.

Calculations of the Errors of the Time-keepers Green and Blue, in ſeveral Periods of ſix Weeks, by compariſon of their going in ſeveral Periods of ſix Weeks, with their going in the ſeveral preceding Periods of ſix Weeks, and alſo with their going in each preceding Week.

Period of ſix Weeks.	Error of Watch Green, by compariſon with preceding Period of ſix Weeks.	Error of Watch Green, by compariſon with preceding Week.	Period of ſix Weeks.	Error of Watch Blue, by compariſon with preceding Period of ſix Weeks.	Error of Watch Blue, by compariſon with preceding Week.
1789.	′ ″	′ ″	1789.	′ ″	′ ″
Aug. 5 to Sept. 16	+ - - 0. 19	+ - - 0. 43	Aug. 5 to Sept. 16	— - - 0. 19	— - - 0. 2
12 — Sept. 23	+ - - 0. 24	+ - - 0. 34	12 — — 23	— - - 0. 3	+ - - 0. 6
19 — Sept. 30	+ - - 0. 23	+ - - 0. 26	19 — — 30	+ - - 0. 2	+ - - 0. 6
26 to Oct. 7	+ - - 0. 15	— - - 0. 2	26 to Oct. 7	+ - - 0. 12	+ - - 0. 17
Sept. 2 — — 14	+ - - 0. 3	— - - 0. 39	Sept. 2 — — 14	+ - - 0. 20,	+ - - 0. 20
9 — — 21	— - - 0. 24	— - - 0. 51	9 — — 21	+ - - 0. 27,	+ - - 0. 28
16 — — 28	— - - 0. 33	— - - 0. 26	16 — — 28	+ - - 0. 30,	+ - - 0. 28
23 to Nov. 4	— - - 0. 24	— - - 0. 11	23 to Nov. 4	+ - - 0. 37,	+ - - 0. 18
30 — — 11	— - - 0. 5	+ - - 0. 30	30 — — 11	+ - - 0. 50,	+ - - 0. 40

APPENDIX, N° XVI, *continued.*

Period of six Weeks.	Error of Watch Green, by comparison with preceding Period of six Weeks.	Error of Watch Green, by comparison with preceding Week.	Period of six Weeks.	Error of Watch Blue, by comparison with preceding Period of six Weeks.	Error of Watch Blue, by comparison with preceding Week.
	′ ″	′ ″		′ ″	′ ″
Oct. 7 to Nov. 18	+ - - 0. 13	+ - - 0. 43	Oct. 7 to Nov. 18	+ - - 0. 48	+ - - 0. 16
14 — — 25	+ - - 0. 44	+ - - 1. 6	14 — — 25	+ - - 0. 49	+ - - 0. 27
21 to Dec. 2	+ - - 1. 29	+ - - 1. 59	21 to Dec. 2	+ - - 1. 4	+ - - 1. 0
28 — — 9	+ - - 1. 44	+ - - 1. 28	28 — — 9	+ - - 1. 11	+ - - 1. 22
Nov. 4 — — 16	+ - - 1. 38	+ - - 0. 17	Nov. 4 — — 16	+ - - 1. 5	+ - - 0. 19
11 — — 23	+ - - 1. 30	+ - - 0. 28	11 — — 23	+ - - 0. 47	— - - 0. 9
18 — — 30	+ - - 1. 27	+ - - 1. 9	18 — — 30	+ - - 0. 39	+ - - 0. 23
1790.			1790.		
25 to Jan. 6	+ - - 1. 3	+ - - 0. 7	25 to Jan. 6	+ - - 0. 28	+ - - 0. 4
Dec. 2 — — 13	+ - - 0. 22	— - - 0. 52	Dec. 2 — — 13	- - - 0. 0	— - - 1. 0
9 — — 20	+ - - 0. 10	+ - - 0. 24	9 — — 20	— - - 0. 11	+ - - 0. 6
16 to Feb. 1	+ - - 0. 5	— - - 0. 35	16 to Feb. 1	— - - 0. 12	— - - 0. 21
23 — — 8	— - - 0. 1	— - - 0. 17	23 — — 8	— - - 0. 10	— - - 0. 7
30 — — 15	— - - 0. 1	+ - - 0. 26	30 — — 15	— - - 0. 4	+ - - 0. 32
1790.			1790.		
Jan. 6 — — 22	+ - - 0. 9	+ - - 0. 41	Jan. 6 — — 22	+ - - 0. 4	+ - - 0. 26
13 to Mar. 1	+ - - 0. 10	+ - - 0. 8	13 to Mar. 1	+ - - 0. 5	— - - 0. 5
20 — — 8	+ - - 0. 14	+ - - 0. 37	20 — — 8	+ - - 0. 3	+ - - 0. 10

Feb.	1	to	March	15	—	-	-	0. 56	—	-	-	1. 27	Feb.	1	to	March	15	—	-	-	0. 10	—	-	-	0. 55
	8	—	—	22	+	-	-	0. 17	—	-	-	0. 10		8	—	—	22	—	-	-	0. 5	—	-	-	0. 7
	15	—	—	29	+	-	-	0. 16	-	-	-	0. 0		15	—	—	29	—	-	-	0. 9	—	-	-	0. 5
	22	to	April	5	+	-	-	0. 17	+	-	-	0. 21		22	to	April	5	—	-	-	0. 9	—	-	-	0. 8
Mar.	1	—	—	12	+	-	-	0. 32	+	-	-	1. 24	Mar.	1	—	—	12	+	-	-	0. 13	+	-	-	0. 50
	8	—	—	19	+	-	-	0. 34	+	-	-	0. 49		8	—	—	19	+	-	-	0. 33	+	-	-	0. 51
	15	—	—	26	+	-	-	2. 35	+	-	-	1. 32		15	—	—	26	+	-	-	0. 51	+	-	-	0. 53
	22	to	May	3	—	-	-	0. 10	—	-	-	7. 50		22	to	May	3	+	-	-	0. 45	+	-	-	0. 14
	29	—	—	10	—	-	-	0. 40	—	-	-	1. 16		29	—	—	10	+	-	-	0. 41	+	-	-	0. 32
April	5	—	—	17	—	-	-	1. 15	—	-	-	1. 35	April	5	—	—	17	+	-	-	0. 29	—	-	-	0. 4
	12	—	—	24	—	-	-	2. 39	—	-	-	2. 0		12	—	—	24	+	-	-	0. 4	—	-	-	0. 33
	19	—	—	31	—	-	-	2. 27	—	-	-	2. 17		19	—	—	31	—	-	-	0. 35	—	-	-	1. 37
	26	to	June	7	—	-	-	3. 45	—	-	-	1. 30		26	to	June	7	—	-	-	0. 57	—	-	-	0. 57
May	3	—	—	14	—	-	-	2. 40	—	-	-	1. 30	May	3	—	—	14	—	-	-	1. 0	—	-	-	0. 31
	10	—	—	21	—	-	-	2. 36	—	-	-	1. 33		10	—	—	21	—	-	-	1. 1	—	-	-	0. 12
	17	—	—	28	—	-	-	2. 16	—	-	-	0. 2		17	—	—	28	—	-	-	0. 54	—	-	-	0. 10
Sums of the Errors without regarding their Signs					-	-	-	37. 45	-	-	-	40. 55	Sums of the Errors without regarding their Signs					-	-	-	19. 27	-	-	-	18. 11

APPENDIX, N° XVII.

An Account of Dr. Bradley's Obſervations.

DR. Bradley's valuable obſervations were made in the courſe of twenty years, from 1742 to 1762, and conſiſt of thirteen volumes in folio. They were removed from the Royal Obſervatory, before I was appointed to the care of it, by the Doctor's executors, who thought proper to conſider them as private property; and during a ſuit inſtituted on the part of the crown, in the exchequer, to recover them, they were preſented, in 1776, to Lord North, now Earl of Guilford, chancellor of the Univerſity of Oxford, and by him preſented to the Univerſity, on the condition of their printing and publiſhing them. The Univerſity put them immediately, for that purpoſe, into the hands of Dr. Hornſby, Savilian Profeſſor of Aſtronomy, and Aſtronomical Obſerver, at the new Obſervatory founded and endowed by the truſtees of the Radcliffe money, whoſe bad ſtate of health has been alledged as the cauſe of the delay of the publication. Being in great want of theſe obſervations, to compare with my own, I addreſſed a letter, on the 23d of December laſt,

to

to the Rev. Dr. Cook, Vice-chancellor of the Univerſity of Oxford, of which the following is a copy:

Royal Obſervatory at Greenwich,
Dec. 22d, 1791.

Sir,

FROM the very reſpectable office which you hold in the Univerſity of Oxford, you are doubtleſs informed, that about the year 1776 the Univerſity received the late Dr. Bradley's aſtronomical obſervations, made at the Royal Obſervatory at Greenwich, whilſt he was Aſtronomer Royal, as a preſent from Lord North, now Earl of Guilford, their Chancellor, on the condition of their printing and publiſhing them; and that, ſince that time, a part of them has been printed, under the inſpection of the Savilian Profeſſor of Aſtronomy, though not yet publiſhed.

From my firſt eſtabliſhment in this honourable poſt, to which his Majeſty was graciouſly pleaſed to appoint me, near twenty-ſix years ago, I have always ardently wiſhed to obtain the uſe of them. They were made with inſtruments conſtructed by the beſt artiſts, and moſt of them new ones, provided at the public expence, on the joint requeſt of Dr. Bradley and the viſitors of the Royal Obſervatory, and are highly intereſting to

Aſtronomers

Aſtronomers in general. They are more particularly intereſting to myſelf, as being in the poſſeſſion of and in the uſe of the ſame inſtruments with which they were made. I want, and have long wanted them, to compare with my own obſervations, and to direct my future ones to important points capable of compariſon with them, leading to a more perfect knowledge of the motions of the heavenly bodies, for which the Royal Obſervatory was eſtabliſhed.

I am in poſſeſſion of all the original obſervations made by my predeceſſors at the Royal Obſervatory, except thoſe by Dr. Bradley; the want of which makes a chaſm of twenty years in the ſeries from 1676, the date of the foundation of the Royal Obſervatory, to the preſent time.

For theſe reaſons, Sir, I requeſt you will favor me with a fair copy of theſe obſervations as far as they are printed, and indulge me with the ſheets in future as they ſhall be worked off from the preſs, if it is in your power to diſpoſe of them; or, if otherwiſe, to convey my requeſt in the moſt reſpectful manner to the learned Univerſity, over which you preſide, or the delegates of the preſs, or whatever body or committee have the diſpoſal of them, to grant me that favor.

All my obſervations made at the Royal Obſervatory from 1765, to the end of laſt year, have been printed and publiſhed, by order of

his

his Majeſty, at the public expence, under the direction of the preſident and council of the Royal Society; by whom copies have been ſent, and will be continued annually, to your Bodleian Library, and new Obſervatory, built and endowed by the truſtees of the Radcliffe money, and the Savilian Profeſſor's Library. I requeſt the return of the like favor in a copy of Dr. Bradley's obſervations; and, from your known liberality and regard to ſcience, I flatter myſelf you will exert your beſt endeavors to fulfil my requeſt.

I am,
Sir,
Your moſt obedient Servant,
NEVIL MASKELYNE,
Aſtronomer Royal.

A Copy.

To the Rev. the Vice-chancellor of
the Univerſity of Oxford.

I received an anſwer from the Vice-chancellor, dated January 27th 1792, that the delegates of the preſs had that day taken my letter into conſideration; and that he was requeſted by that Board to ſay, that proper directions ſhall be given for a copy of Dr. Bradley's Aſtronomical Obſervations to be ſent to me as ſoon as the work ſhall be ready for publication, which they are uſing every method to expedite.

I had

I had flattered myſelf with the hopes of a more favorable anſwer than this, which did not come up to the terms of my requeſt, *viz.* to be favored with an immediate copy of Dr. Bradley's obſervations, as far as they were printed, and with the ſheets in future as they ſhall be worked off from the preſs.

NEVIL MASKELYNE.

THE END.